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PHYSICS.—*Some experiments relating to the electrical conductivity of the lower atmosphere.*[1] G. R. WAIT, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

The factors that affect the electrical conductivity of the Earth's atmosphere vary considerably with altitude above the ground. In the present paper the discussions are intended to apply to those conditions that are encountered specifically in the Earth's lower atmosphere, that is, in the portion accessible to measuring instruments. There will be briefly described some of the more commonly employed methods of measuring the conductivity and a presentation made of a few results of measurements at some widely separated localities. Attention will also be called to some of the more important factors affecting this element, and finally some experiments will be described that have been carried out for the purpose of gaining a better understanding of the manner and the extent to which these factors operate in regulating and controlling the conductivity of the lower atmosphere.

It is well to bear in mind that, while considerable effort has been devoted to the isolation and the evaluation of various factors that affect the conductivity of the atmosphere at considerable altitudes, little attention has been given to such problems concerning the lower atmosphere. The greatest effort has been devoted to measurements of this conductivity, in order to secure a knowledge of its magnitude and character of variation with time and place under various conditions. Little effort has been given to learning why the conductivity varies in any particular manner. The desire to learn more concerning the underlying factors that contribute to the control of the conductivity of the lower atmosphere and how they operate has been a stimulus to the initiation of the experiments to be discussed.

The air about us is one of the best insulating substances known, comparing closely with amber, which is widely used and valued because of this peculiar property. Its conductivity is so small that it was long a question whether it existed at all. A conductor in air was found many years ago to lose its electric charge gradually. It was thought, however, that this might be due to the slow escape of charge over its supports. Coulomb, more than 160 years ago, first observed that the charge on a conductor inside a vessel disappeared at a rate proportional to the amount of charge on the body and that this rate appeared too great to be accounted for by the loss over the insulating supports. He believed that the air did actually conduct electricity and explained this on the basis of molecules of air coming into contact with the conductor, then being repelled with a resulting transfer of charge to the walls of the surrounding vessel. Later investigations, including those by Matteucci, Warburg, Boys, and Linss, furnished further evidence that the loss of charge by a conductor in air is not entirely due to its escape over the insulating supports. It was not, however, until the beginning of the present century that definite proof of this was obtained. H. Geitel and C. T. R. Wilson in the same year carried out experiments that took complete account of

[1] Address of the Retiring President of the Philosophical Society of Washington, delivered at the 1258th meeting of the Society on January 4, 1946. Received August 27, 1946.

the loss of charge over the supporting insulators and found that the surrounding air did conduct electricity. In Geitel's experiments a correction was applied for the loss over the insulators. In Wilson's experiments the arrangement was such that a loss of charge over the insulating supports was prevented from occurring.

Experiments at the Cavendish Laboratory, at the beginning of the century under the direction of J. J. Thomson, threw considerable light upon the manner in which a gas conducts an electric current. The conductivity of a gas was observed to increase under the influence of X-rays and radioactive matter. When such influences were withdrawn, the conductivity of the gas gradually returned to normal. The conductivity was also found to diminish when the gas passed through glass wool and when it was slowly drawn between highly charged metal plates. To explain such electrical characteristics it appeared necessary to assume that the action of the X-rays and the radioactive matter was such as to produce electrically charged particles of both signs in the gas. The glass wool filtered the charged particles out of the gas while the action of the field between the charged plates removed the charged particles from the gas to the plates. The oppositely charged particles, after being produced, gradually recombined, thus accounting for the gradual reduction of the conductivity of the gas after the removal of the X-rays or radioactive matter. The charged particles in the gas were called "ions," as were also the charged particles in an electrolyte, which render the electrolyte electrically conducting. The ions in a gas similarly give the gas its conductivity, the positive and negative ions accounting for a positive and negative conductivity, respectively.

A number of different types of apparatus have been developed for the measurement of the conductivity of the air. One of the earliest was that devised by Elster and Geitel [see *1* of "References" at end of paper] in Germany during the early part of the present century. It consisted essentially of an electroscope to which was connected a small metal cylinder on which an electric charge could be placed. Over this cylinder another and larger earthed cylinder was fitted in order to protect it from the disturbing influences of the Earth's field. It was later shown that the measurements with this apparatus were somewhat open to question. It was used by E. Schweidler without the outer cylinder and in a location where it was not subjected to the Earth's electric field. In this way more accurate values of the conductivity were secured. Another and more precise method of measuring the conductivity of the air was developed by Schering (*2*), likewise in Germany. In the more improved form of the Schering apparatus a horizontally stretched wire, some 20 meters in length, is surrounded by an earthed open-mesh wire cylindrical screen at a distance of about 50 cm. The horizontal wire is connected electrically to an electrometer, which in some cases was adapted for automatic recording work. This type of apparatus has had considerable use at various stations in Europe in recording the conductivity of the air. Swann (*3*) showed that this type of apparatus, however, is subject to considerable error under conditions of little wind. He also pointed out the importance of installing the apparatus where it would not be influenced by the Earth's electric field.

The apparatus that is most commonly used today and that is free from the objections raised against most of those previously developed was designed by Gerdien (*4*) and described by him in 1905. It consists essentially of a cylindrical condenser, the inner member of which is connected electrically with an electrometer or electroscope. A fan draws a stream of air at a more or less constant rate through the outer cylinder. The inner cylinder, after being isolated from a battery, gradually loses its charge by catching oppositely charged ions which are drawn out of the passing stream of air. From the rate at which this electrode loses its charge, together with the constants of the apparatus, the conductivity of the air may be computed.

An improved form of Gerdien apparatus was designed by Swann (*5*) at the Department of Terrestrial Magnetism for automatically recording the conductivity of the air. The improvements included (1) the use

of a more sensitive electrometer, the steady deflections of which depend upon the value of the conductivity, and (2) means for the avoidance of an error which occurs in the earlier form of apparatus and which is due to the collection of radioactive matter on the cylindrical condenser.

Measurements of the conductivity were carried out over the ocean aboard the experimental vessel *Galilee* as early as 1907 by the Department of Terrestrial Magnetism. Later measurements were made over the ocean aboard the *Carnegie* on the six cruises from 1915 to 1921, and on the seventh cruise during 1928 and 1929. Continuous records of the conductivity have been obtained by the Department at several land stations since 1917, when the first recording apparatus was installed on top of the main laboratory building in the suburbs of Washington. At the present time continuous records of the conductivity are being obtained at three widely separated land stations, namely, the Watheroo Magnetic Observatory in Western Australia, the Huancayo Magnetic Observatory in Peru, at an altitude of 3,350 meters, and the Tucson Magnetic Observatory of the Coast and Geodetic Survey in Arizona.

The value of the conductivity of the lower atmosphere varies greatly from place to place over land and has both a diurnal and a seasonal variation. The causes for such variations will be discussed later. In Fig. 1 is shown the type of automatic daily record being obtained at the Department's observatories. In the reproduced records of positive and negative conductivity from Huancayo one sees that a zero point is obtained each hour. This zero is the result of the removal of all ions from the air-stream before it reaches the central cylinder. Between zeros the magnitude of deflection from the zero position affords a measure of the conductivity. The apparatus is a duplex system that records simultaneously the positive and negative conductivity. The bottom record is for the Earth's electric field (potential gradient) for the same day. This field results from an electric charge on the Earth's surface. The daily variation in potential gradient, as may be seen, is largely

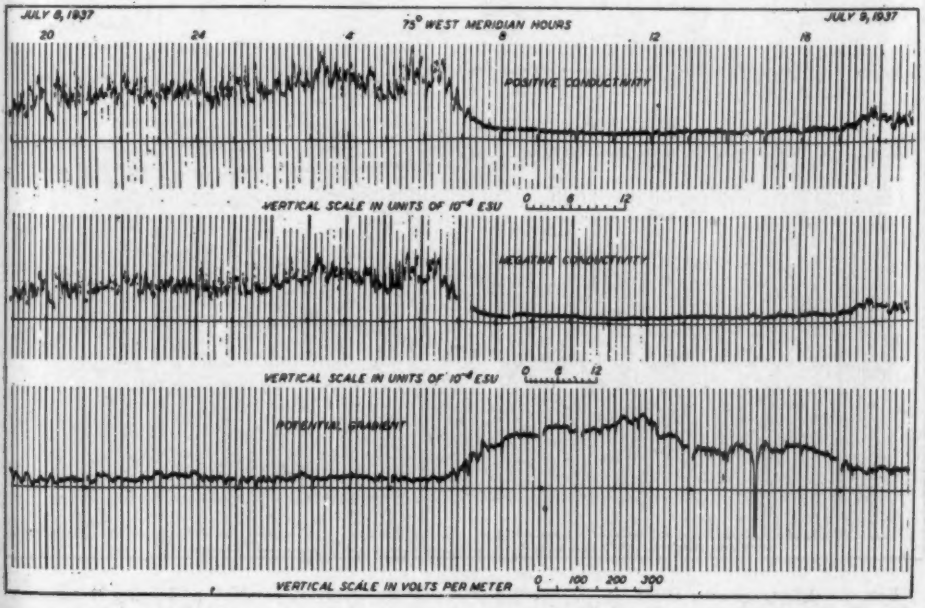

FIG. 1.—Electrograms, Huancayo Magnetic Observatory, "quiet" day during dry season.

opposite in character to that for the conductivity. This is due to changes in the conductivity of the atmosphere. Whether or not a decrease in conductivity is accompanied by an increase in potential gradient depends on whether this decrease is confined to a relatively thin layer of the atmosphere or whether it extends throughout the entire vertical column of the atmosphere. It might be explained that as a consequence of the Earth's charge an electric current passes to the Earth through the atmosphere and is known as the "air-earth current." From Ohm's law one can write $G=i/\lambda$, where G is the value of the potential gradient, i is the value of the air-earth current density, and λ is the total conductivity of the air. If the value of λ varies only in a thin layer of the atmosphere, the value of i is not appreciably affected; consequently

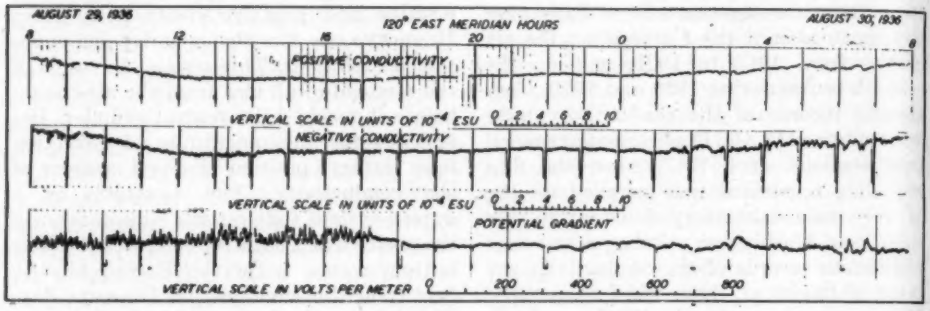
AUGUST 29, 1936
120° EAST MERIDIAN HOURS
AUGUST 30, 1936
POSITIVE CONDUCTIVITY
VERTICAL SCALE IN UNITS OF 10⁻⁴ ESU
NEGATIVE CONDUCTIVITY
VERTICAL SCALE IN UNITS OF 10⁻⁴ ESU
POTENTIAL GRADIENT
VERTICAL SCALE IN VOLTS PER METER

FIG. 2.—Electrograms, Watheroo Magnetic Observatory, "quiet" day.

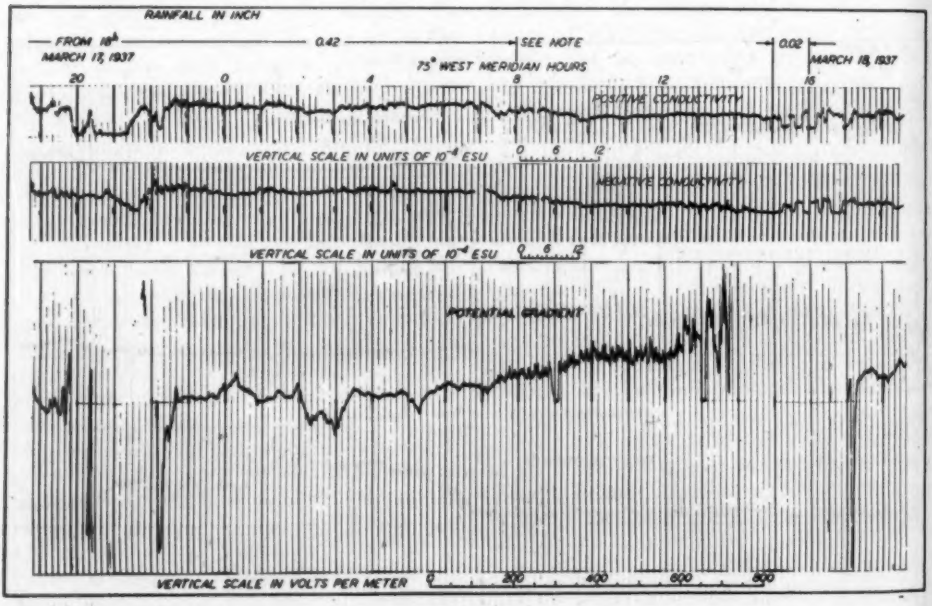

FIG. 3.—Electrograms, Huancayo Magnetic Observatory, rainy day. (Note: Clearing in morning after 10h.5, early afternoon March 18, increasing cloudiness, distant rain, and thunder to southwest at 14h).

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the gradient in this layer will vary as the value of $1/\lambda$. Since this is the type of daily variation found at Huancayo, it is concluded that such changes in conductivity are confined to a relatively thin layer of the lower atmosphere. On the other hand, if the decrease in conductivity occurs uniformly throughout the entire vertical column of the atmosphere, the value of both i and λ will be diminished in the same proportion. The value of the ratio i/λ, and consequently that of G, will then remain unaltered. This is largely the condition prevailing at Watheroo, as may be seen from Fig. 2, which shows a typical fair-weather diurnal-variation curve for the conductivity of each sign and for the potential gradient. During a thunderstorm not only is the potential gradient often disturbed but the conductivities may also be affected when these disturbances are great. In Fig. 3 is shown the type of record frequently obtained during a thunderstorm. The bottom curve represents the atmospheric potential gradient at Huancayo, which was recorded simultaneously with the conductivities of both signs. It is apparent that, at times of very intense electric fields, the conductivity of the air was likewise disturbed. The effect, in general, is such as to cause a diminution in the value of the conductivity of only one sign. The conductivity of the opposite sign at that particular time appears more or less undisturbed. The sign affected depends upon whether the potential-gradient curve is above or below the base line. When above the base line, the potential gradient is positive (negative charge on the ground) and the negative conductivity is affected. When below, the opposite takes place. That is, the sign of conductivity affected is always the same as that of the charge on the ground below the point of observation. The reduced conductivity, which is due to reduced number of ions per unit volume in the atmosphere, is attributed to the fact that the intense field removes the ions almost as fast as they are produced.

The conductivity of the air over the open ocean proceeds generally uniformly with time. The influences of land areas may often be observed many miles out to sea. This may be illustrated by the record of conductivity of the air over the ocean as obtained aboard the *Carngeie* during her last cruise, and shown in Fig. 4. It is apparent that the conductivity was steady relatively far from land, but less steady near land. Incidentally, the conditions determining the ionic equilibrium over the ocean, and hence the average value of the conductivity of the air over this region, appear to undergo a gradual change through the years. The change is of such a nature as to cause a gradual decline in the conductivity. To illustrate the character and magnitude of such changes, a plot of the mean conductivity over various areas of the oceans is shown in Fig. 5, the data of which were obtained aboard the *Carnegie*. Each point on this plot represents the mean conductivity for a particular leg of a cruise. Each mean is composed of a number of observations since in general one set was taken each day. For example, in the case of the leg labeled Europe-America, there were 13 observations for the 1913 point and 20 observations for that of 1928. A possible cause for the decline in conductivity will be discussed later.

The presence of appreciable quantities of smoke has a marked effect upon the conductivity of the air. This is illustrated by the diurnal-variation curves of the conductivity at Watheroo, together with curves for certain other atmospheric-electric elements which are shown in Fig. 6. Two sets of curves for the conductivity are given, one for the case when there was considerable smoke in the air, the other with little smoke. It is apparent that the presence of smoke reduces the conductivity. The manner in which this is accomplished will be taken up later in this article. It might be noted, however, that the value of the air-earth current density is also reduced when smoke is present. Since the dimunition of the current is relatively less than that of the conductivity, the decrease in the latter does not extend throughout the entire vertical column. That is, the smoke does not extend all the way up to the upper conducting layer.

The average value of the conductivity of the air varies considerably from place to

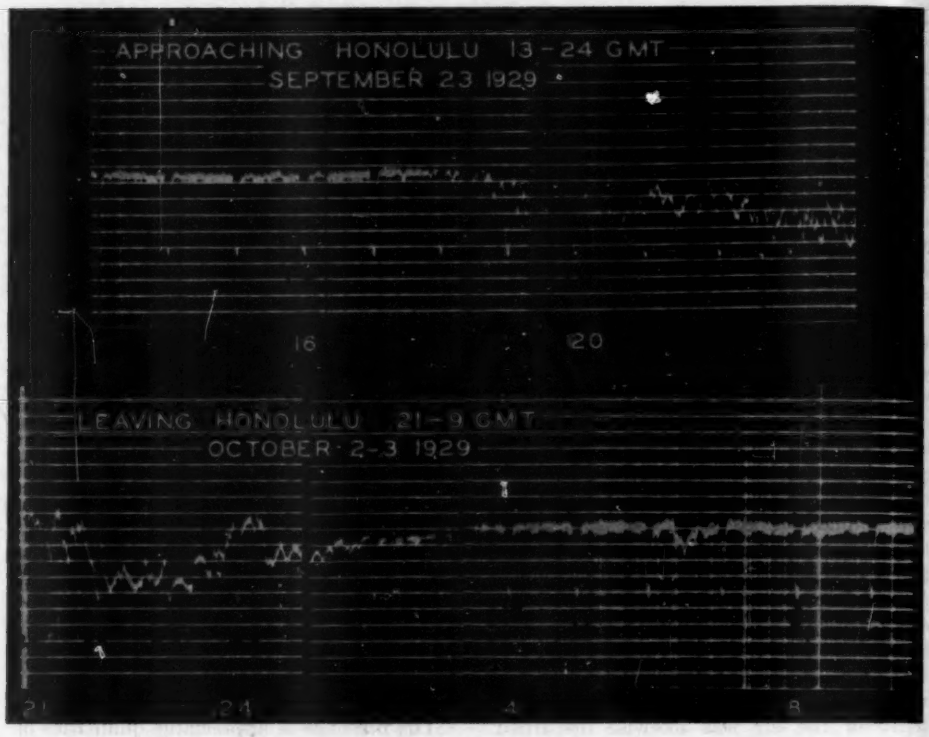


FIG. 4.—Air conductivity over the ocean recorded on the *Carnegie*.

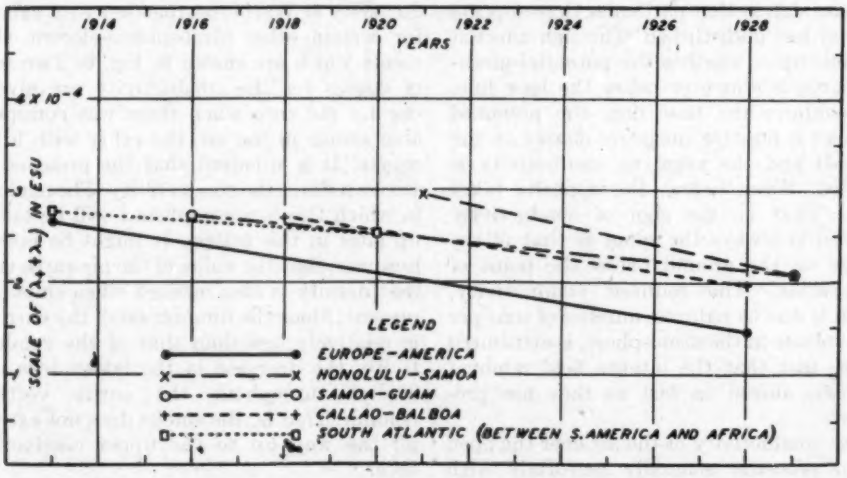


FIG. 5.—Decline through the years in conductivity of air over the ocean.

place over land as illustrated by diurnal variation curves for the total conductivity (positive plus negative) for two seasons of the year for the three land stations as shown in Fig. 7. The mean conductivity at Huancayo is somewhat greater than that usually encountered over land and that at Washington is somewhat less. The lower air pressure at a high altitude station such as Huancayo will result in an increased conductivity due to an increase in velocity of the ions. Neither the high values observed at this station, as compared with those observed at Washington, nor the large

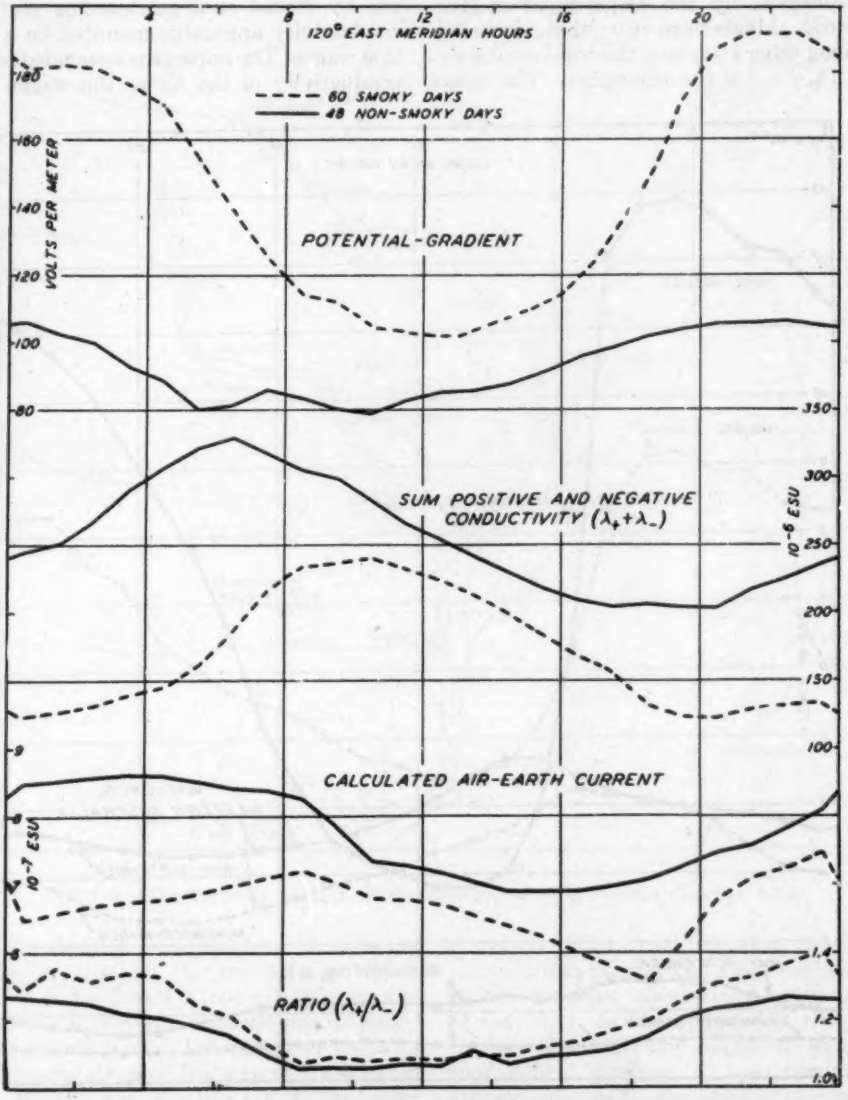


FIG. 6.—Diurnal variation of atmospheric-electric elements at Watheroo for smoky and non-smoky days during February, 1925–1934.

amplitude can be entirely explained in this way. The conductivity of the air at Washington, on the other hand, is very low, attributable in part to the influence of the city. To secure information concerning the influences of a city on various atmospheric electric elements, a survey was carried out several years ago in and about the city of Washington by the Department of Terrestrial Magnetism (*6*) that included, among other elements, the total conductivity ($\lambda_+ + \lambda_-$) of the atmosphere. The values of the total conductivity during this survey are given on the map shown in Fig. 8. Within the city limits, as may be seen, the values are much smaller than those in the nearby rural areas, the smaller values being confined to a rather restricted region within the city. As a further check on these results, a more recent but briefer survey was carried out by means of a quick-acting portable conductivity apparatus mounted on a station wagon. The apparatus responded to the conductivity of the air as the wagon was

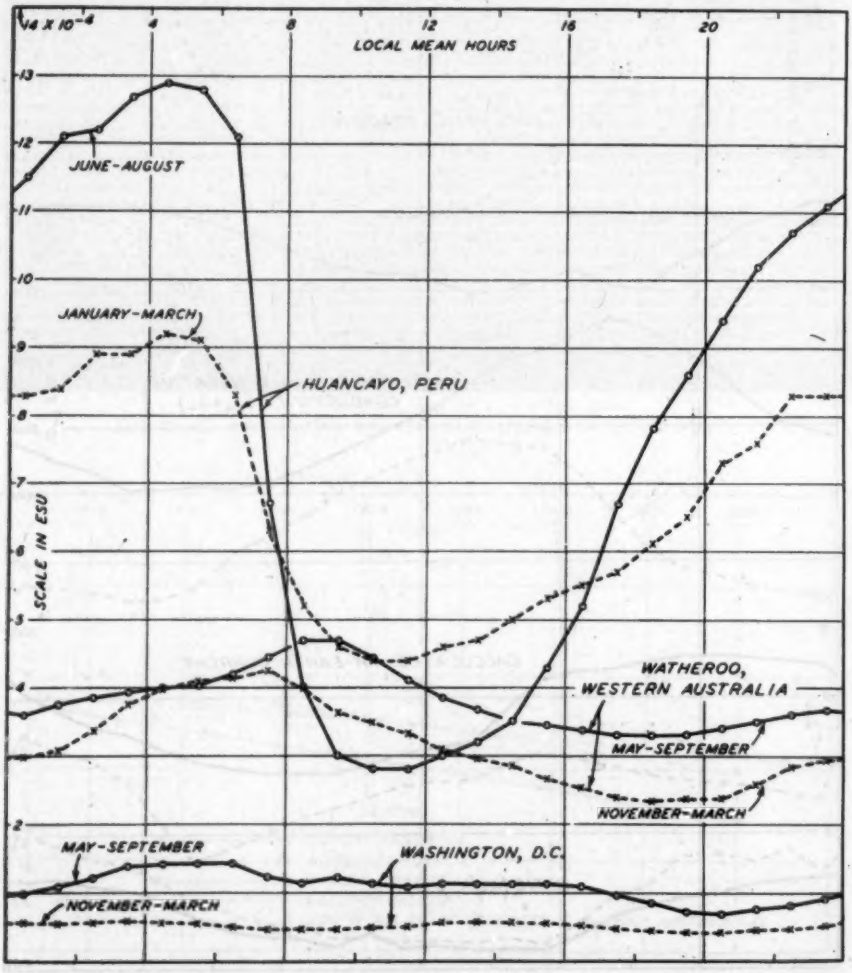


FIG. 7.—Total conductivity of atmosphere for 1930, at Watheroo, Huancayo, and Washington.

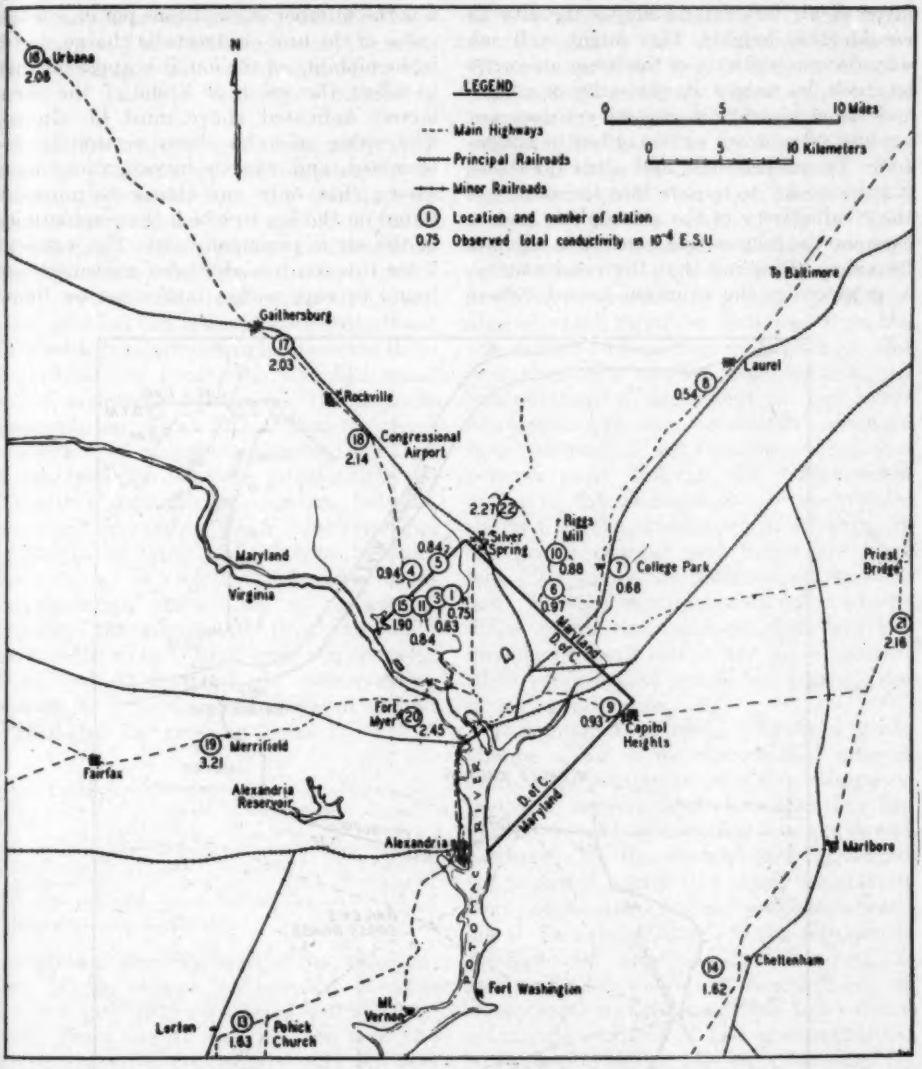


FIG. 8.—Conductivity of air in Washington area observed during October, 1930.

driven along the road at about 20 miles per hour, so that all the results were taken within a few hours of one another. On the previous survey the observations extended over several weeks. The results of the later survey are given on the map of Washington and vicinity and shown in Fig. 9. The agreement in the results of the two surveys is extremely good, both showing very low values within the city and a gradual increase to higher values, amounting to some three or four fold, as one approaches the open country. What are the conditions within a city which produce a less conducting atmosphere? Such conditions, one might point out, are not confined to the surface

layer of air but extend above the city to considerable heights. One might well ask why the conductivity of the lower air varies as much, let us say, as one order of magnitude from place to place and yet does not amount to so much as two orders of magnitude. To answer these and other questions it is necessary to inquire into the causes of the conductivity of the atmosphere and to examine the factors that control or regulate its value. Recalling that the conductivity, λ, is given by the equation $\lambda = nek$, where n is the number of small ions per cc, e is the value of the unit electrostatic charge, and k is the mobility of the ion, it is apparent that to affect the value of λ one of the three factors indicated above must be altered. The value of e has been accurately determined, and various investigations have shown that only one charge is normally found on the ion to which the conductivity of the air is principally due. The value of k for this ion has also been measured and found to vary within rather narrow limits

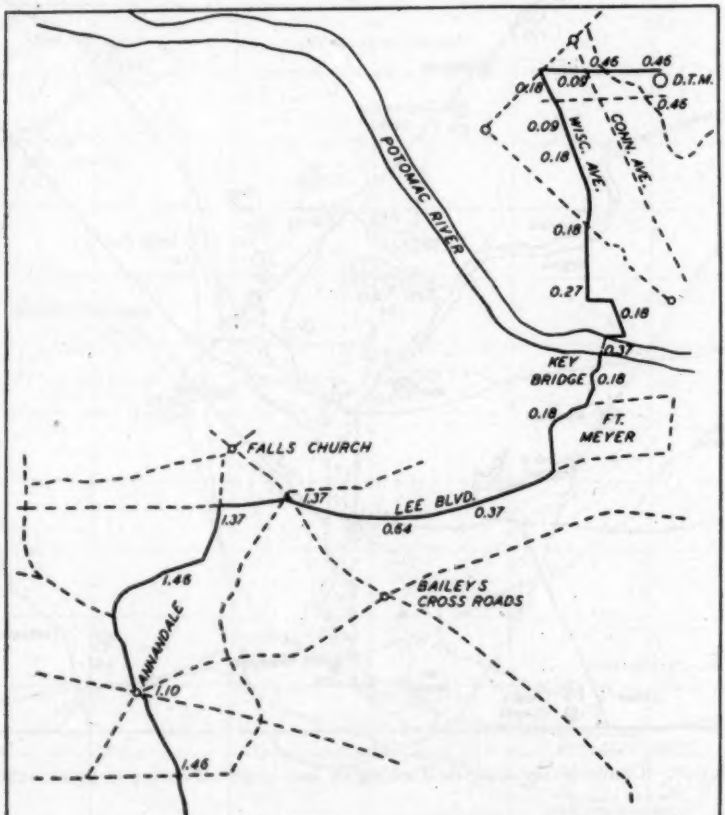


FIG. 9.—Electrical conductivity of the atmosphere (in 10^{-4}esu), Washington, D. C., and vicinity, March 21, 1945.

for conditions encountered in the lower atmosphere. The remaining factor, the number of ions per unit volume, must be the principal variable and the controlling factor.

Only one type of ion has been referred to thus far in discussing the conductivity of the atmosphere because the conductivity may be attributed almost exclusively to it. All the types of ions present in the atmosphere however, contribute to the conductivity; to obtain the total conductivity, one must sum up the individual contributions. In Washington, for example, there are three discernible ion types, the so-called small ion of molecular dimensions, the large or Langevin ion, which has a diameter about two orders of magnitude greater than that of the small ion, and the intermediate ion (7) with a diameter intermediate between the other two types. The conductivity due to the three types of ions thus becomes $\lambda = e(nk + n_i k_i + NK)$ in which e represents the electronic charge and n, n_i, and N represent the number per cc of the small, intermediate, and large ions respectively; k, k_i, and K represent the corresponding mobilities. Typical values observed around Washington are given in Table 1:

TABLE 1

	Small ions	Intermediate ions	Large ions
Number per cc...	200	150	5000
Mobility[1].....	1.5	0.7	5×10^{-4}

[1] Values are in cm/sec/volt/cm.

Calculating the conductivity by substitution of the above values one obtains: $\lambda = 4.3\times10^{-7}[100+3.5+0.8] = 0.45\times10^{-4}$ ESU. From this it may be seen that the intermediate ion contributes only 3.5 percent, while the large ion contributes only 0.8 percent of that contributed by the small ion.

The large ions do not generally contribute in great measure to the conductivity of the lower atmosphere; their importance is due to the influence they exert upon the number of small ions present. Hence, the large ions set a limit to the value of the conductivity and, if numerous, regulate the value of the conductivity of the atmosphere. Thus, we have an explanation of the very low value of conductivity for the smoky days at Watheroo and also that obtains within the city, and the relatively higher value in the open country districts. Within the city, for example, the large ions are relatively more abundant than in the rural areas. The reason for this is that they are produced abundantly in the exhaust gases of automobiles and by practically all other forms of combustion. The particle that is liberated in such a process acts as a center or nucleus around which moisture condenses from the atmosphere to form fog, mist, or cloud and is known as a condensation nucleus. All condensation nuclei found in the lower atmosphere do not necessarily originate from combustion, but this plays a most important part. Not all the condensation nuclei in the atmosphere are electrically charged. In Washington about a fourth are electrically charged and hence are large ions. The number of positive and negative large ions are approximately equal except under special circumstances. Just why the number of small ions in the air is reduced when condensation nuclei are present, deserves consideration.

The number of small ions in a given volume of air, if we assume that none is mechanically brought into the volume or removed, depends upon how fast they are produced and how fast they recombine and combine with the charged and uncharged condensation nuclei. In a closed vessel freed from condensation nuclei the equation leading to ionic equilibrium, if the number of positive and negative ions is equal, is $dn/dt = q - \alpha n^2$, where α is the coefficient of recombination of the small ions. In a volume containing charged N and uncharged N_0, condensation nuclei, this equation must be modified in view of the combinations between the nuclei and the small ions. If the positive and negative large ions are equally numerous the corresponding equation becomes $dn/dt = q - \alpha n^2 - \eta N n - \eta_0 N_0 n$, where N and N_0 are the number per cc of charged nuclei of one sign and uncharged nuclei respectively while η and η_0 are the coefficients of combination between the small ions and the respective nuclei. Under equilibrium conditions for large ions and condensation

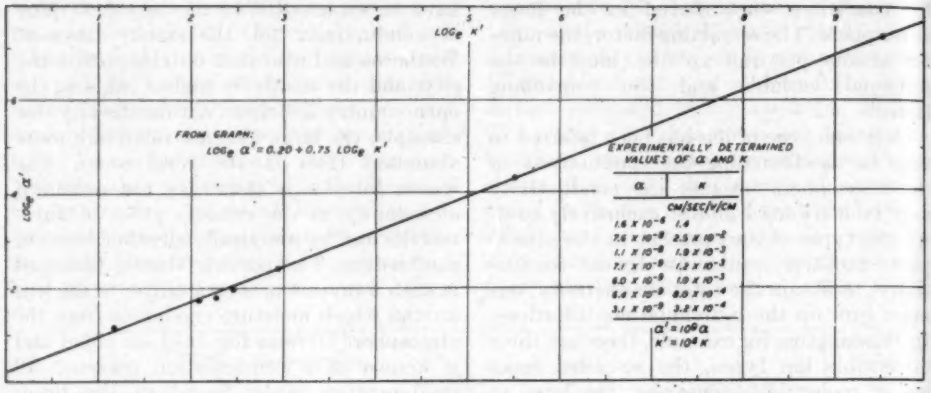

LOG$_e$ K'
FROM GRAPH:
LOG$_e$ α' = 0.20 + 0.75 LOG$_e$ K'
LOG$_e$ α'
EXPERIMENTALLY DETERMINED VALUES OF α AND K
α
K
CM/SEC/#/CM
1.6 X 10^{-6} 1.4
7.6 X 10^{-8} 2.5 X 10^{-2}
1.1 X 10^{-8} 1.9 X 10^{-3}
7.1 X 10^{-9} 1.2 X 10^{-3}
6.0 X 10^{-9} 1.0 X 10^{-3}
6.4 X 10^{-9} 8.0 X 10^{-4}
3.1 X 10^{-9} 3.2 X 10^{-4}
$\alpha' = 10^8 \alpha$
K' = 10^4 K

FIG. 10.—Empirical relationship between mobility (K) and recombination coefficient (α) of gaseous ions.

nuclei, the relation may be written approximately $\eta Nn = \eta_0 N_0 n$, hence, when $dn/dt = 0$, $q = \alpha n^2 + 2\eta Nn$. For average conditions in Washington the value of the term αn^2 is only a few percent of the quantity $2\eta Nn$ and may be neglected in nearly all cases, whence, the above equation becomes $q = 2\eta Nn$. For a constant value of q, the number of small ions per cc is consequently inversely proportional to the number of large ions.

A similar equation involving the number of condensation nuclei, N_A, per cc in the place of the number of large ions may be written in view of the known relationship between the number of charged and uncharged condensation nuclei. The number of condensation nuclei is equal to the sum of charged and uncharged nuclei, that is, $N_A = N_1 + N_2 + N_0$. If every charged nucleus has a single charge then N_1 and N_2 refer to both the number of unit charges and to the number of charged condensation nuclei, positive and negative, respectively. If we assume on the basis of the above equation that $\eta Nn = \eta_0 N_0 n$ and $q = 2\eta Nn$, it follows that $q = 2\eta/[(\eta/\eta_0) + 2] N_A n$, which may be rewritten $q = 2\omega N_A n$ where ω acts as the combination coefficient between small ions and condensation nuclei. To test the validity of the above equation it is necessary to secure not only measurements on the number of small ions per cc but also on the number of condensation nuclei.

An apparatus was developed more than 50 years ago by John Aitken (*8*), a Scotch engineer, for counting condensation nuclei in the atmosphere. A small model of a larger laboratory apparatus, which he carried in his coat pocket, was used by Aitken and is the type of instrument most commonly used today. The apparatus operates on a principle similar to that of the Wilson cloud chamber. It employs an air pump by which the air pressure in a small chamber is suddenly reduced. The resulting expansion of air is not sufficient to permit the condensation of moisture (water being present in a saturated blotter) around small ions, as in the case of the Wilson cloud chamber, but it does permit the condensation around the nuclei because this takes place at a lower supersaturation. Visible droplets of water thus formed fall under the force of gravity, and the number of nuclei per cc in the outside atmosphere is determined from the number of droplets falling, if the volume of air used as a sample and the constants of the instrument are known.

Two separate instruments are used for counting the ions of the atmosphere, since a single instrument can not be suitably designed for counting both the large and the small ions. The small-ion counter as used at the Department is so placed that the air-stream enters this instrument before it enters the large-ion counter. The small and large ions are, therefore, taken from the same sample of air. Each ion-counter is provided with its own electrometer, the deflections of which provide a measure of the

number of ions collected. These apparatus have been used extensively to record ion-content of the open air and in closed rooms.

In the development of the equation $q=2\eta Nn$ we considered as negligible the recombination between large ions. Though it is quite certain that the recombination coefficient α for this ion is small, there is some doubt as to the value for the large ion found in the air. Kennedy made the first determination of the value of α and obtained 6.3×10^{-10}. Later Hogg obtained a value of 1.7×10^{-8}. The value of α varies with the size of the ion, and it seems probable, therefore, that Hogg's measurements applied to a smaller ion. Although size of the ion can not be directly determined, it may be inferred from the value of the mobility K, which can be measured. Under the circumstances it was considered important that determinations be undertaken of both α and K for the same ion. The writer has accordingly made measurements over a wide range of mobilities. The lowest mobility is applicable to the large ion of the atmosphere (10^{-4} cm/sec/v/cm), while the highest is about two orders of magnitude greater. Only a summary of the results will be presented without describing the methods employed in the determinations. The values of α and K are found to fit an empirical equation of a simple form. The plot of $\log_e \alpha'$ against $\log_e K'$ results in a straight line that includes the values by others for the small ion shown in Fig. 10, from which it is seen that $\log_e \alpha' = D + S \log_e K'$, where $\alpha' = 10^6\alpha$, $K' = 10^4 K$, and where S and D are constants having the values 0.75 and 0.20, respectively. Unfortunately, no adequate theoretical consideration has been given to any possible relationship between α and K. A recent consideration by W. E. Harper applies only to pressures of about 10 atmospheres and consequently fails to meet the need in the present instance.

In correlating the total nuclei and the large ions it is important to know whether each large ion carries more than one charge. Determinations of the number of unit charges per large ion have been made at the University College, Dublin, in ordinary room air. Mr. Torreson and the writer (*9*) made similar determinations in the laboratory in Washington for ions in outdoor air as well as for ions artificially produced from burning gas. To determine the charge per ion the following procedure was followed: the nuclei-content, N_A, of the air is taken before it enters the ion counter and again after it has passed through the counter, the latter count giving the number (N_0) of uncharged nuclei. The difference between the total number of nuclei and the number of uncharged nuclei ($N_A - N_0$) represents the number of charged particles. The total number of charged particles is then compared with the total number of unit charges measured with the large ion counter to obtain the charge per ion. The results by Nolan, Boyland, and deSachy, at Dublin, for room air show that the charge per ion is unity. From the results by Torreson and the writer similar results were found for the outside air in Washington and for ions artificially produced from burning gas. Table 2 illustrates the results obtained in the latter case. From all these results it seems justifiable to assume that in general the charge per large ion is unity as has previously been found for the small ion.

TABLE 2.—NUMBER OF PARTICLES IN CHAMBER (180 CUBIC METERS) AFTER EXTINGUISHING FLAME, CORRESPONDING NUMBER OF UNIT-CHARGES PER ION, AND PROPORTION OF PARTICLES UNCHARGED.

Time minutes	Particles per liter			$\frac{N_A - N_0}{2.15}$	Number of unit-charges per particle	Percent of particles uncharged
	Total (N_A)	Uncharged (N_0)	Positively charged (N_+)			
5	175.6	141.5	15.85	15.90×10^2	1.00	81
6	128.0	95.0	15.32	15.35×10^2	1.00	74
7	97.5	67.5	14.50	13.95×10^2	1.04	69
8	89.0	60.0	13.76	13.49×10^2	1.02	67
9	88.0	60.0	13.42	13.02×10^2	1.03	68
10	87.5	60.0	12.85	12.80×10^2	1.00	69
11	87.0	60.0	12.39	12.56×10^2	0.99	69
12	86.5	60.0	11.95	12.33×10^2	0.97	69
Means					1.01	71

Simultaneous records of the small and the large-ion content of the outdoor air in Washington, D. C., were obtained by Mr. Torreson and the writer (*9*) over the period of a year beginning in October 1932. The resulting data have been separated according to seasons and are shown in the form of

diurnal variation curves in Fig. 11. The large-ion content of the air during the cold season is considerably greater than during the warm season. This is in large part due probably to the increase in smoke and gases given off by domestic fires. The diur-

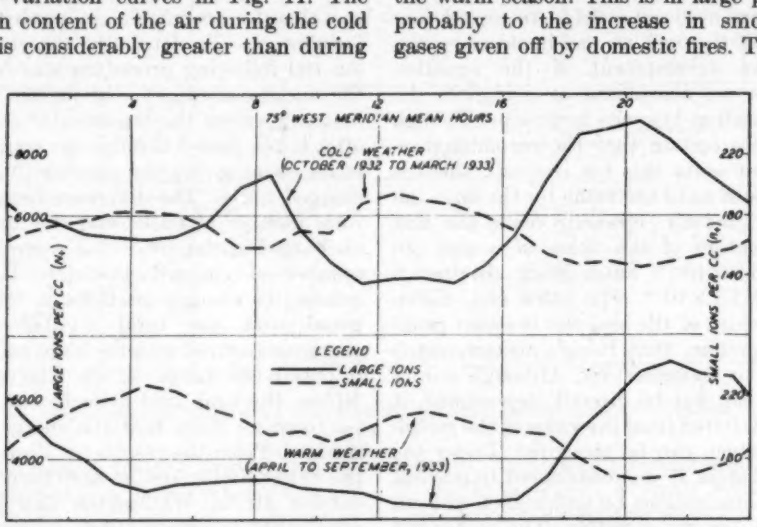


FIG. 11.—Seasonal diurnal—course in positive large ions and positive small ions—cold weather (October 1932 to March 1933) and warm weather (April to September 1933), Washington, D. C.

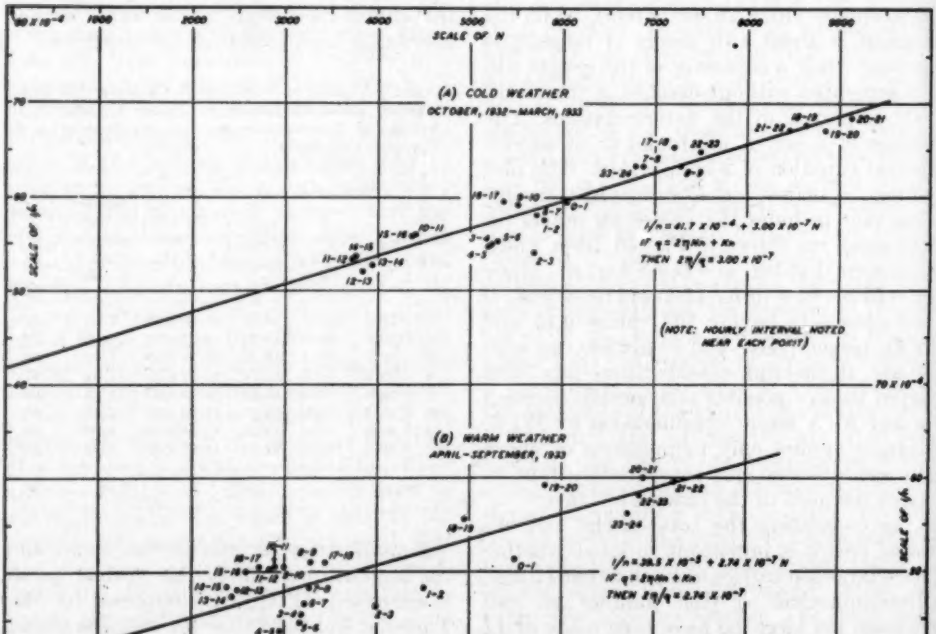


FIG. 12.—Relation between large and small ions at Washington, D. C.

nal variation in large ions is to be explained probably in a similar manner. The small-ion content varies more or less in a manner inverse to that of the large-ion content for both seasons as is to be expected on the basis of the equation $q=2\eta Nn$. For a better quantitative comparison of the inverse relationship between the two types of ions in the air, the reciprocal $1/n$ of the small-ion content is plotted against each corresponding value of the large-ion content for the two seasons, and the resulting curves are shown in Fig. 12. From the relationship indicated by the two curves it is seen that the value of $1/n$ varies directly as the value of N, but it is not zero when the value of N is zero. The general relationship between the two elements is expressed in the equation $1/n=AN+K'$. The value of q is usually regarded as approximately constant, and the equation may be rewritten as: $q=2\eta Nn+Kn$. It indicates that the small ion is removed from the atmosphere not only through combination with charged and uncharged nuclei but also by some other process since the ordinate at the intercept is too great to be accounted for by recombination of the small ions. One possible explanation of such removal is by attachment to gross particles which are too large to be counted either by the large-ion counter or the nuclei counter. Recently J. J. Nolan (*10*), of University College, Dublin, found a similar relationship between the small-ion content and the condensation-nuclei content of the air, employing data from four land stations. These results taken with those obtained in Washington give further indication of a need for a revision of the equation as given above.

We have shown that variations in the numbers of condensation nuclei alter the number of small ions, but since the number of small ions is also affected by q, the rate at which they are produced, special consideration must be given to the variation of q with time and the factors that govern its variation. The ionization, or production of small ions in the atmosphere, is chiefly attributable to the cosmic rays and radiations from radioactive matter in the soil and atmosphere, as indicated in Table 3. Radioactive matter, such as radium, thorium, and actinium, is found distributed throughout the Earth's crust. As these elements decay, there are formed radon, thoron, and actinon, which behave chemically like the group of inert gases, argon, neon, etc. These gases tend to escape from the soil into the air. There occur, therefore, in the atmosphere not only radioactive gases but also each successive radioactive product such as radium *A*, radium *B*, etc. All the radioactive gases as they decay give off alpha rays only. Some of the decomposition products give off alpha rays only, others beta and gamma rays, and still others all three. A precise determination of q can be secured by measuring the effects not only of the beta and gamma rays but also of the alpha particles, which are so easily stopped that they can penetrate only a few centimeters of air.

TABLE 3.—IONIZATION[1] OF THE AIR BY COSMIC RAYS AND BY RADIOACTIVE MATERIALS IN THE SOIL AND AIR.

Radioactive material	Source of ionization (In percent of total)				Total	
	α	β	γ	Cosmic rays		
Radium in air	30	1	1	—	32	51
Thorium in air	18	1	—	—	19	
Radium in soil	—	1	32	—	33	
Thorium in soil				16	16	
Total.....	48	3	33	16	100	

[1] As estimated by Hess.

In view of the difficulties, previous attempts were confined to rough estimates of q, obtained at a particular time, never continuously, or throughout a whole day. But even such attempts to estimate the character of the diurnal variation were regarded as of considerable importance.

In our investigations use was made of an ionization chamber and electrometer, arranged to give an automatic record of the ionization inside the chamber. The walls of the chamber were constructed of sufficiently thin material to permit the penetration of alpha particles from the radioactive matter outside producing ions within. Thin cellophane (the alpha-ray stopping power of

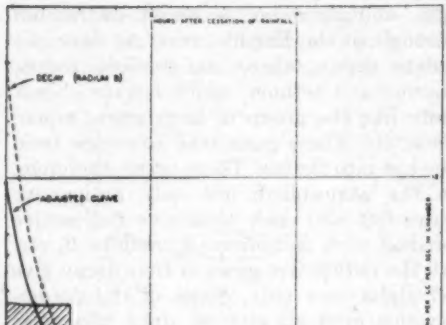


FIG. 13.—Ionization-decay following thundershower (mean 8 showers, Washington, D. C., summer 1933).

which corresponded to about one and one-half centimeter of air) stretched over an open mesh brass cylindrical screen, was used to form the outer wall.

The complete ionization of the outside atmosphere can not be measured by such an apparatus because a portion of the alpha particles are absorbed while passing through the wall and because the radioactive matter enclosed within the chamber gradually decays. The apparatus is, however, capable of furnishing interesting and valuable information concerning the variations in q of the outside atmosphere.

During the first summer of operation it was frequently found that during an intense thunderstorm the ionization of the air increased by as much as 100 or 200 percent. McNish and the writer have investigated this matter (*11*) and have found that the most rapid increase in ionization generally occurs with the beginning of the heaviest rainfall. After the passing of the storm the rate of ionization slowly returns to normal. The rate of return closely coincides with the rate of decay of radium *B*, as may be seen

FIG. 14.—Measured rate ion-production inside thin-walled chamber, Washington, D. C.

from the curves of Fig. 13. These results are interpreted to mean that, at the time of the formation of the thunderstorm, convective action carries radioactive matter from the vicinity of the ground into the clouds, where it is dissolved in the moisture of the cloud. As the clouds pass the station the radioactive matter is brought down with the rain, thus increasing the amount already present. A thundercloud, in accordance with this theory, contains radioactive matter in a greater or lesser amount. This radioactive matter will result in an increase in the electrical conductivity of the air in the vicinity of the cloud.

The rate of ionization of the air near the ground was found to vary considerably with the condition of the soil. A reduction in value occurs when the soil is covered with snow and when it is wet. These results are illustrated by Fig. 14, which permits a comparison of diurnal variation curves of the rate of ionization when the soil is dry with that when it is wet and also when the ground is covered with snow with that when it is not. It is apparent that the wet soil and also the covering of snow have appreciably reduced the rate of ionization of the air. The reduction in the case of the wet soil was greatest during the early-morning hours, thus altering somewhat the character of the diurnal variation curve. In attempting an explanation of the reduced ionization in the two cases cited, it should be recalled that much of the ionization of the air is due to the presence of radioactive matter and that this matter originates from radioactive gases that came from the soil. A blanket of snow and the moisture in the small capillaries in the soil inhibit the escape of the radioactive gases and consequently reduce the amount of radioactive matter in the atmosphere resulting in a reduction in rate of ionization.

From the curves just shown it is apparent that an important diurnal variation occurs in the rate of production of small ions in the lower atmosphere with somewhat different characteristics in summer and winter. The rate of production for both seasons passes through a maximum during the early-morning hours and a minimum during the evening. The diurnal variation is more pronounced in summer than in winter. It is probably due to the fact that during the night hours radioactive matter accumulates in the lower atmosphere and is dispersed vertically as the wind increases in morning hours. It is probable that the more pronounced convective air currents are responsible for the greater diurnal variation in summer. This diurnal variation, together with that of large ions, accounts in large part for the diurnal variation in conductivity of the air.

It seems reasonable to suppose that a fall in barometric pressure has a tendency to drive radioactive gases from the soil. An increase in temperature of the soil would have a similar effect. As a consequence, the amount of radioactive matter in the air would show an increase under such circumstances. Some observers seem to have found an increase in the radium *A* content of the air with a falling barometer and also with an increase in temperature while others have found no such effects. McNish and the writer have secured continuous records of the ionization of the atmosphere for both decreasing barometric pressure and increasing temperature here in Washington; the results are shown in Fig. 15. Inspection of the curves fails to disclose any important changes in the ionization with changes in barometric pressure or temperature, thus indicating that any effect is not pronounced. Any possible relationship can, therefore, be disclosed only by statistical treatment employing a considerable number of data.

For some of the tests the apparatus for counting the small and large ions was set up in the main building where, it was hoped, conditions would be more uniform and to some extent subject to control. It was believed that the various elements to be measured, in contrast to results obtained outside, would probably not vary greatly through the day. The measurements soon proved this belief to be fallacious. On Sundays no diurnal variation was observed. On other days it was found to be large. Furthermore, the variations suggested dependence on the occupancy of the building by people. When they came to work in the morning the number of large ions in the room began to increase and the

number of small ions, as a result, to decrease. When the building was vacated at night the reverse changes occurred. Throughout the week there appeared to be superimposed on the systematic diurnal variation a gradual accumulation of large ions in the room and the number of small ions accordingly showed a gradual decrease in number. At 1 o'clock on Saturday, when occupancy of the building terminated for the weekend, the number of large ions began gradually to decrease. This decrease prevailed until Monday morning when the building was again occupied. The number of small ions always showed the opposite changes in rather faithful detail. These results are summarized by the curves shown in Fig. 16. Not all the reasons for these changes have as yet been ascertained; two of the more important, however, are as follows: (1) Tobacco smoke from other parts of the building entered the room in spite of attempts to seal the room from other parts of the building, and no smoking occurred in the room itself; (2) particles, considerably larger than those constituting tobacco smoke, are given off in the human breath and accumulate in the air of the room. Many of the particles in the tobacco smoke and in the breath are electrically charged and are consequently large ions. Other tests have shown conclusively that every exhaled breath contains several hundred million particles, the great major-

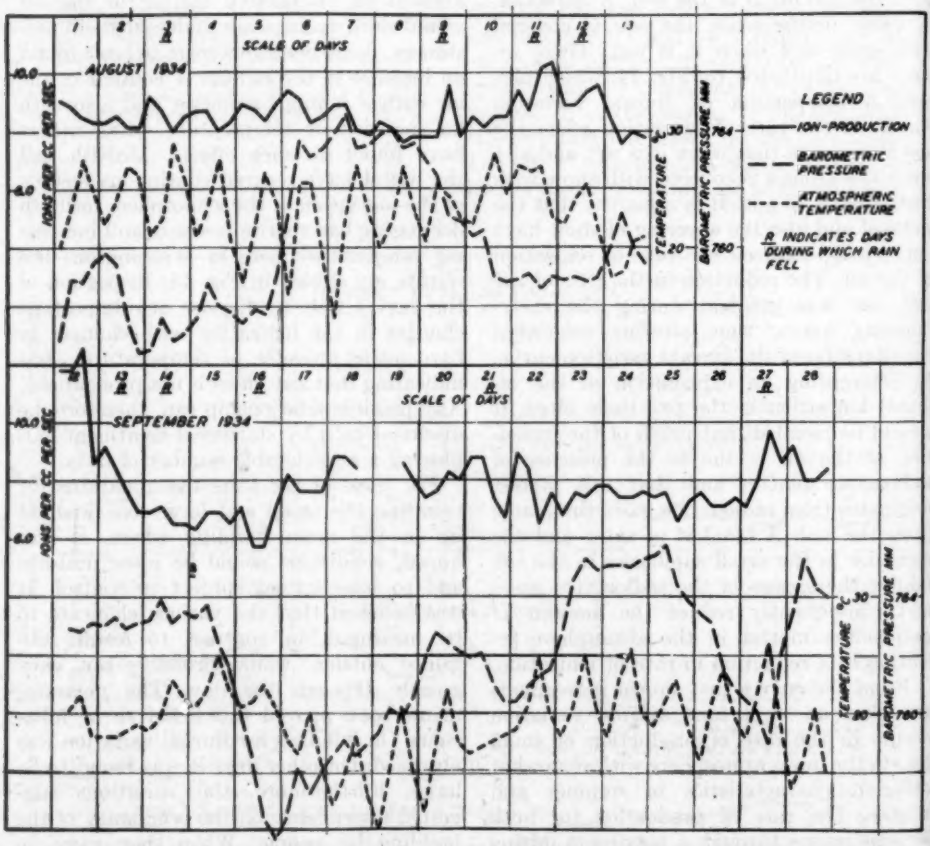


FIG. 15.—Rate of ion-production in closed chamber and meteorological conditions—means 6-hour intervals at Washington, D. C.

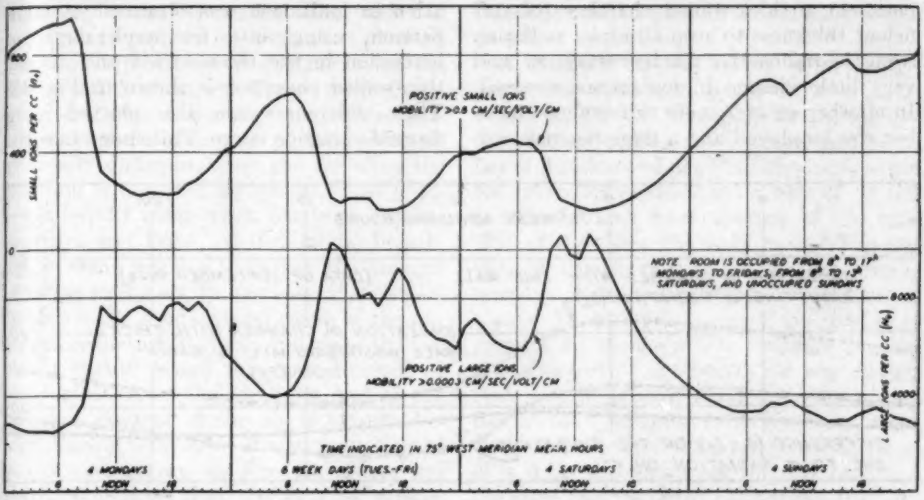

SMALL IONS PER CC (N+)
POSITIVE SMALL IONS
MOBILITY >0.8 CM/SEC/VOLT/CM
NOTE ROOM IS OCCUPIED FROM 8h TO 17h
MONDAYS TO FRIDAYS, FROM 8h TO 13h
SATURDAYS, AND UNOCCUPIED SUNDAYS
POSITIVE LARGE IONS
MOBILITY >0.0003 CM/SEC/VOLT/CM
LARGE IONS PER CC (N+)
TIME INDICATED IN 75° WEST MERIDIAN MEAN HOURS
4 MONDAYS
6 WEEK DAYS (TUES.-FRI.)
4 SATURDAYS
4 SUNDAYS
NOON

FIG. 16.—Effect of occupancy on numbers of small and of large ions inside room 210 in main laboratory, Department Terrestrial Magnetism, Washington, D. C., November 17 to December 7, 1933.

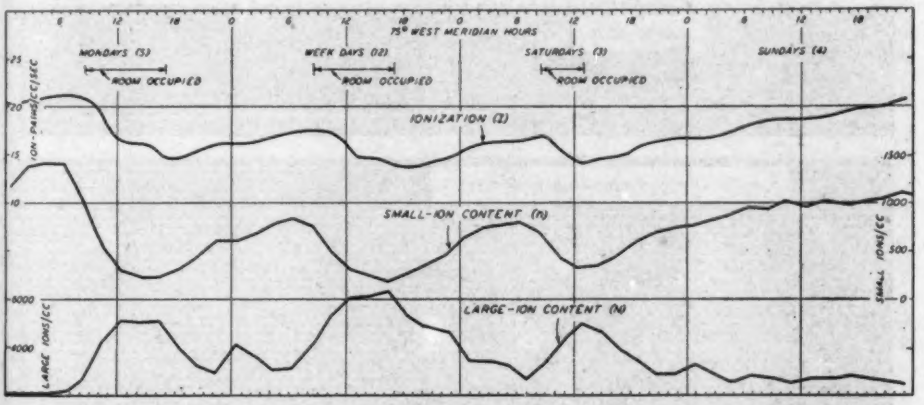


FIG. 17.—Ionization, small-ion content and large-ion content in room 211, Department of Terrestrial Magnetism, February 1938.

ity of which are probably electrically charged and nearly equally divided between the two signs. Incidentally, the presence of these particles makes it possible for us to see our breath on a cold day (to use the popular expression) because the particles act as condensation nuclei.

Upon measuring the ionization with a thin-walled chamber inside our laboratory room it was found that this element also underwent a diurnal variation suggestive of an effect due to people occupying the building. In Fig. 17 are shown diurnal variation curves for this element and those for the small- and large-ion content of the air. The days are grouped to provide curves for Mondays, Saturdays, other week days, and Sundays. From these curves it is seen that the ionization varies in a manner similar to that of the small-ion content. In one ex-

periment a thick-walled chamber (of sufficient thickness to stop all alpha radiation from the radioactive matter) was used, and very little change in ionization occurred. In another an extremely thin-walled chamber was employed and a large diurnal variation in ionization was observed. A comparison, using data for week days, of ionization in the thick-walled and a very thin-walled chamber, is shown in Fig. 18. Their differences are also plotted as a diurnal variation curve. This shows how the

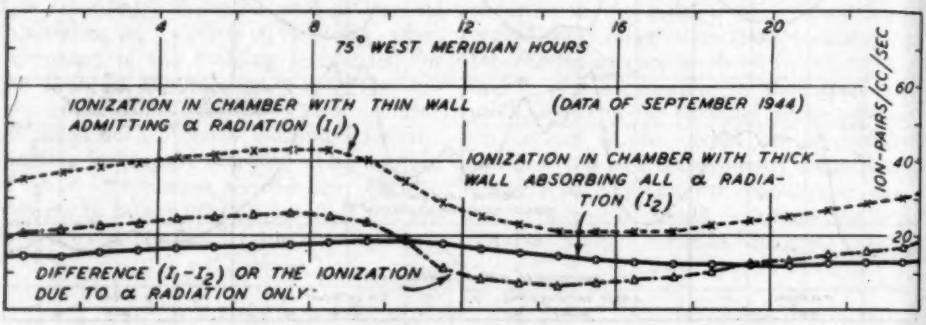


FIG. 18.—Ionization measurements in closed laboratory room of building occupied by people only during work hours.

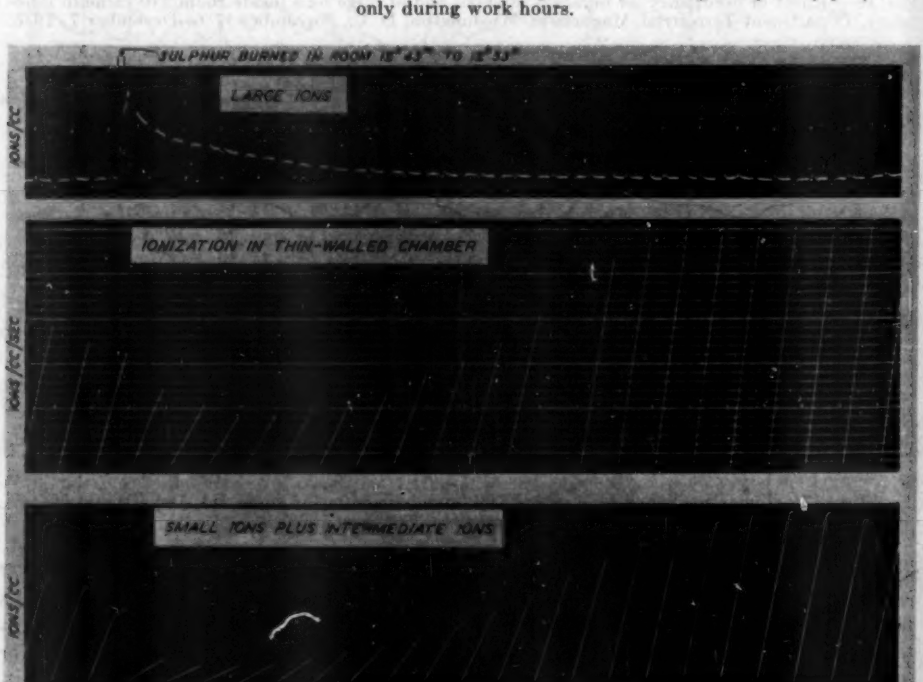
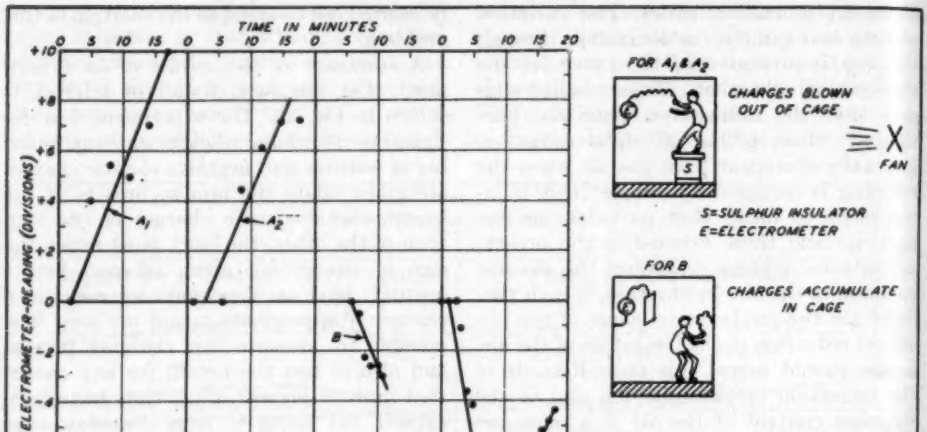


FIG. 19.—Records in closed room showing effect of burning sulphur on large ions, ionization in thin-walled chamber, and small ions plus intermediate ions, March 19–20, 1934 (potential of ionization-chamber negative with respect to earth).

alpha-ray ionization varies. The variation of beta and gamma ray ionization through the day is presented in the curve for the thick-walled chamber. These results suggest that the radioactive materials, particularly those giving off alpha radiation, gradually disappear from the air when the building is occupied by people. This is interpreted to mean that particles, smoke-particles and those exhaled in the breath, act in some manner to reduce the amount of radon in the air. In any case, if such particles are the fundamental cause of the observed reduction in the ionization of the air, a test should reveal this fact. Records of the ionization of the small-ion and of the large-ion content of the air of a room before, during, and after the introduction of smoke, are shown in Fig. 19. These are clear indications that smoke does reduce the ionization of the air as measured with a thin-walled chamber.

There seems to be no simple way of accounting for a reduced amount of radon in the air resulting from the introduction of smoke or other particles. Air containing a large number of these particles has an increased stopping power for alpha radiation. Calculation clearly indicates, however, that this effect is small and can not account for the change in ionization as observed. The agglomeration of particles and the adherence of radioactive matter to them increases the rate at which they fall out of the air. It is impossible to reject entirely this explanation. Preliminary tests, however, make it appear unlikely that radioactive material is removed from the air in this way. Other possible ways of accounting for the observed results might be suggested. One might, for example, point to the increased tendency for radioactive matter to cling to solid objects particularly when associated with electrically charged particles in the air. However, if radioactive matter clings to both the cellophane-covered chamber and the walls of the room without distinction, one would expect a resulting increase and not a decrease in the measured ionization of the air. At present no attempt will be made to explain observed results. It is hoped that additional experiments may be carried out to assist in the solution of this problem.

A summary of the results of an experiment that has been found of interest is shown in Fig. 20. The experiment was designed to determine whether an equal number of positive and negative electric charges are given off in the human breath. If the breath contains more charges of one sign than of the other, the body must retain the sign of charge not given off and consequently have a tendency to assume a charge. If appropriate means are used it is possible to measure this charging process and also to test the breath for any charge that may be present. Such tests have been carried out using a large Faraday cage composed of copper-wire screen in the form of a cube. A human subject was put into the cage and insulated electrically from it, his wrist being connected electrically, using a cloth moistened with a salt solution, to the fiber system of a single-fiber electrometer. The electrometer was placed inside and its outside case connected to the cage. As seen from the curve, the electrometer fiber gradually drifted in a direction which indicated that the subject was receiving, or in this instance was retaining, a positive charge. A second subject gave the same results and essentially the same rate of charging which corresponded to a current of about 10^{-14} amperes. If the human system retains a positive charge, it must give off a negative charge. In a second experiment an arrangement permitted the charge retained by the body to pass to the cage and thence to ground, while any charge in the breath remained inside the cage. With the electrometer fiber now connected to an insulated plate the electrometer through induction will show a response to the charged breath of the same direction as if this sign of charge were applied directly to the fiber system. In this experiment the electrometer fiber drifted in a direction indicating that a negative charge was accumulating in the cage as was to be expected. The rate of drift, considering the relative capacities of the system in the two instances, was quantitatively of the right amount to agree with that found in the



SUMMARY OF RESULTS

CURVE	dV/dt	CURRENT C(dV/dt)	UNIT CHARGES PER BREATH
	VOLTS/SEC	AMPERES	
A_1	4.4×10^{-4}	2.9×10^{-14},	7.2×10^5
A_2	4.2×10^{-4}	2.8×10^{-14},	6.8×10^5
B	4.3×10^{-4}	2.8×10^{-14},	6.8×10^5
C	7.2×10^{-4}	2.4×10^{-14}*	—
D	3.0×10^{-4}	1.0×10^{-14}*	—

† IF C=60 CM * IF C=30 CM

FIG. 20.—Experiments demonstrating that people exhale negative and retain positive charges.

first experiment. On the assumption that the human breath contains a negative space-charge, then it was deemed possible to obtain the effect by placing the subject outside the cage and blowing the charges into the cage with an electric fan. Two subjects were so placed and a fan so situated that their breaths would be gently blown into the cage. The gradual drift of the electrometer fiber again indicated that the breath is negatively charged, and that the quantitative agreement with the previous tests is good. The subjects were suddenly removed from the vicinity of the cage while the fan continued to blow as before. The electrometer fiber drifted back toward zero, thus indicating that the space-charge was gradually removed from the cage, as was to be expected. Additional tests were made and some repeated, all showing the same general results. The above results indicate that each breath contains about 700,000 more negative than positive charges. From other tests, which I am unable to discuss at this time, it is estimated that each breath contains around a thousand times this number of each sign. That is to say, in a thousand positive charges given off in the breath, there will, on the average, be one thousand and one negative charges given off. The whole field of breath particles is almost entirely unexplored, and one can only hope that some day it may be more adequately investigated.

SUMMARY

1. To understand why the conductivity of the lower atmosphere varies so greatly with season, through the day, and from station to station, and even in going from city to rural community nearby, it is necessary to understand why the number of small ions varies under those conditions.

2. The number of small ions per cc for equilibrium-conditions depends on two factors—the rate of production and the rate of destruction. The rate of destruction in a locality where there are many condensation nuclei is proportional to the sum of two terms, one containing the number of nuclei per cc and the other approximately a constant for a given time and place.

3. Contributing toward the production of small ions are the cosmic rays and the radioactive material in the soil and air. The amount of radioactive material in the outside air is subject to considerable variation. A blanket of snow and a moist soil reduce the amount of radioactive gas escaping from the soil, and consequently the amount in the atmosphere.

4. An important diurnal variation in the rate of production of small ions occurs. A maximum rate occurs due probably to an accumulation in the air of radioactive matter during the night and the early morning hours. This is probably an important contribution to the early morning maximum in conductivity of the air noted in all the diurnal variation curves shown. The rate of production begins to decline as increased mixing of the air sets in later in the day.

5. The decrease in conductivity of the air during smoky conditions as compared with nonsmoky conditions, shown from the Watheroo data, is due to the destructive effect of smoke particles on the small ions. Likewise, the decreased conductivity in Washington as compared with that in the country districts is largely due to the accumulation in the city of smoke and gases from automobiles, domestic fires, etc., and the destructive effects that the particles in the smoke and gases have upon the small ions.

6. The gradual reduction in conductivity of the air over the ocean is probably due to the gradual accumulation through the years of smoke and gases from ocean-going vessels. It is also possible that some accumulation occurs because of industrial fires on nearby continents.

Thus we see that, like a living thing, the conductivity of the lower atmosphere finds survival increasingly difficult in our modern industrial age. Civilization is taking its toll of this as it is of the many more tangible things.

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PALEOBOTANY.—*Alterations in some fossil and living floras.*[1] ROLAND W. BROWN, U. S. Geological Survey.

Since my last roundup of changes in fossil floras new specimens and new information have appeared and now warrant another statement. Such periodic overhaulings seem to me essential to the progress of paleobotany because they concentrate attention on the weak spots, invite discussion, and stimulate more precise work before publication. Sometimes these revisions find little favor. Thus, E. W. Berry objected (*9*)[2] to some changes I proposed (*18*) in the Eocene Wilcox flora of the Gulf States on the alleged ground that they were unsubstantiated by facts and that his overspeciation was justified by the principle that in the study of a fossil flora "it is a sound method for a refined analysis to precede an attempted synthesis." Space does not permit a detailed reply to these criticisms. In part, however, I herewith submit two new species, *Betula taylorana* and *Comptonia mississippiana*, in support of my opinion that the Wilcox flora contains scattered remains of temperate species.

Although the changes here suggested involve miscellaneous floras, particular attention focuses on the flora of the Latah (Miocene) and related formations in Washington and Idaho. The Miocene collections of the United States National Museum have grown steadily as a result of the generous cooperation of local collectors such as E. E. Alexander, C. O. Fernquist, and Kenneth Buxton, of Spokane, Wash., and Boyd Olson, of Orofino, Idaho. In 1941 I visited many of the Washington and Idaho localities and obtained significant new material, particularly diagnostic fruits and seeds; and in 1943 I. G. Sohn, also of the U. S. Geological Survey, obtained a collection in the Latah formation near Elk River, Idaho. Late in 1945 the Johns Hopkins University deposited in the National Museum all its Mesozoic and Cenozoic plant collections. These include many specimens from South American localities.

Many of the changes here proposed have been projected as a result of consultation with Dr. Daniel I. Axelrod, whose friendly criticism and intelligent collaboration are gratefully acknowledged. He, however, is not to be held responsible for any errors I may have perpetrated.

TROCHILISCACEAE

Trochiliscus greenei (Ulrich) Brown, n. comb.
Moellerina greenei Ulrich (*48*), p. 34, pl. 3, figs. 8, 8a-8e.
Trochiliscus devonicus (Wieland) Peck (*44*), p. 108, pl. 12, figs. 14–21. See synonymy.

In Peck's review of North American Charophyta he discussed *Moellerina greenei* described by E. O. Ulrich as a foraminifer from the Onondaga limestone (Devonian) at the Falls of the Ohio, near Jeffersonville, Ind., and Louisville, Ky. Peck copied (*44*, pl. 9, figs. 2a–2f) Ulrich's figures and pointed out that the spirals of the specimens as figured are sinistral, the only known exception to the rule that the spirals of all pre-Pennsylvanian trochiliscids are dextral. For this reason Peck suspected that the original figures may have been reversed and, as the Ulrich types were thought to be lost, he refrained from using the Ulrich name. The types, however, are not lost but are preserved in the United States National Museum. The spirals are dextral. Dr. Ulrich explained to me on May 8, 1940, that the sinistral spirals were an inadvertence, he having drawn the illustrations by camera lucida directly on lithographic stone. Consequently, in printing, a reversed image of the original resulted.

I see no difference between Ulrich's *Moellerina greenei* and Peck's *Trochiliscus devonicus*, founded on a record and name only by G. R. Wieland, and specimens subsequently collected by Peck at Wieland's locality.

Occurrence: Devonian. Onondaga limestone. Falls of the Ohio, near Jeffersonville, Ind., and Louisville, Ky.

PINACEAE

Pseudolarix bienensis (Hu and Chaney) Brown, n. comb.
Cedrela bienensis Hu and Cheney (*28*), p. 54, pl.

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Received June 28, 1946.

[2] Italic numbers in parentheses refer to the Literature Cited.

30, fig. 3 [not fig. 2, which is *Rhus miosuccedanea* Hu and Chaney].

This winged seed lacks the distinguishing features of *Cedrela* seeds but resembles closely those of the conifers *Keteleeria* and *Pseudolarix*. As the nutlet is rounded rather than triangular and only about one-fourth the total length of the seed I consider that the seed represents *Pseudolarix*. The true identity of this seed necessitates a modification of the statement by Hu and Chaney (pp. 6, 109) that "the Shanwang flora as now known is made up exclusively of angiosperms."

Occurrence: This species is an item in a large flora from an outcrop of laminated Miocene shale, called by the Chinese "the book of ten thousand volumes," near Shanwang in Shantung Province, China.

SALICACEAE

Populus lindgreni Knowlton Fig. 12

Populus lindgreni Knowlton (*29*), p. 725, pl. 100, fig. 3.

Although several species of *Populus* were reported in the first papers on the Latah flora, the specimens subsequently proved assignable to other genera. In recently acquired material, however, there are several authentic examples of *Populus lindgreni* Knowlton, which was described originally from the Payette formation of Idaho, now believed to be synchronous, or nearly so, with the Latah formation.

Occurrence: Miocene. Latah formation. Vera, Wash. (Fig. 12); collected by C. O. Fernquist. East of Orofino, Idaho; collected by Boyd Olson.

MYRICACEAE

Comptonia mississippiana Brown, n. sp. Fig. 9

Leaves as in the living sweetfern, *Comptonia peregrina* (Linnaeus) Coulter, except that the lobes are more acute and in many instances are deeply toothed. Judged by the numerous described species of *Comptonia* the genus was widely distributed in the North Temperate Zone during the Tertiary, but only one species survives and that occupies relatively dry hillsides and open woodland borders from Michigan to Nova Scotia and south to Tennessee.

Occurrence: Eocene. In bauxite-bearing strata low in the Wilcox formation in sec. 36, T. 3 S., R. 2. E., Tippah County, Miss.; collected by Louis C. Conant.

BETULACEAE

Betula taylorana Brown, n. sp. Fig. 14

Leaves 8–15 cm long, acuminate, rounded at the base, with double-serrate margins, the teeth of nearly uniform size, rounded to acute. Secondary veins slightly spreading, straight, or gently curved, the basal pairs branched. Petiole 5–10 mm long. Seven fragments represent this species, which, except for the rounded base, resembles the yellow birch, *Betula lutea* Michaux, of moist uplands and stream banks in eastern North America south to North Carolina and Tennessee.

Occurrence: Eocene. Ackerman formation. Jim Taylor farm in Chester County, 4 miles northwest of Silerton, Hardeman County, Tenn.; collected by F. S. MacNeil.

FAGACEAE

Quercus axelrodi Brown, n. sp. Fig. 13

Leaf oblong-lanceolate to narrowly elliptic. On several smaller specimens the apex is acute and base cuneate to somewhat rounded. Margin entire in basal quarter of the blade, but evenly toothed distad with large, rounded, slightly hooked, blunt-tipped teeth directed toward the apex. Sinuses between the teeth relatively shallow and scalloped. Secondary veins evenly spaced and fairly straight in upper half of the blade, somewhat irregular and spreading in the lower half.

Although these leaves might be compared casually with those of the chestnut oak, *Quercus montana* Willdenow, their sharper, hooked teeth point toward closer comparison with those of the chinquapin oak, *Q. muhlenbergi* Engelmann. The latter species is comparatively rare in the Atlantic States but abundant in the Mississippi Basin.

I name this species for Dr. Daniel I. Axelrod, who has been assiduous in the study of the late Tertiary floras of California and adjoining States.

Occurrence: Miocene. Latah formation. Vera Wash. (Fig. 13); collected by R. W. Brown. Brickyard locality, Spokane, Wash.

ULMACEAE

Zelkova drymeja (Lesquereux) Brown, n. comb.

Rhus? drymeja Lesquereux (*36*), p. 416.

Myrica drymeja (Lesquereux) Knowlton (*32*), p. 394. [Exclude item Knowlton, 1916, p. 256, pl. 20, figs. 1, 2.]

Callicoma microphylla Ettingshausen. Lesquereux (*37*), p. 246, pl. 43, figs. 2–4.
Myrica callicomaefolia Lesquereux (*39*), p. 146, pl. 26, figs. 5–14.
Myrica fallax Lesquereux (*39*), p. 147, pl. 32, figs. 11–14 [not figs. 15, 16].
Ulmus brownellii Lesquereux (*39*), p. 160, pl. 28, figs. 2, 4.
Fagopsis longifolia (Lesquereux) Hollick. Knowlton (*31*), p. 265, pl. 20, fig. 5.

The leaves included in the foregoing synonymy are in general asymmetric, linear-lanceolate in outline, with acute to attenuate apices, and evenly serrate margins, the teeth being single, sharp triangular, and only rarely somewhat rounded to mammillate. The large suite in the Florissant collection of the U. S. National Museum contains no broad-ovate specimens with large round-mammillate teeth. Consequently, I conclude this species differs from *Zelkova hesperia* particularly in this feature and from *Z. nervosa* in having leaves that are more lanceolate in outline.

Occurrence: Oligocene. Lake beds at Florissant, Colo.

Zelkova hesperia Brown, n. sp. Fig. 3

Ulmus brownellii Lesquereux. Chaney (*21*), p. 113, pl. 12, figs. 3, 6, 7, 8; pl. 13, figs. 1, 3, 6. [Exclude the synonymy.]

As the types of *Ulmus brownellii* Lesquereux from Florissant, Colo., are herein referred to *Zelkova drymeja* (Lesquereux) Brown, the species from the Crooked River region of Oregon, being regarded as different, requires a new specific name.

The leaves of this species display considerable variation in outline and dentition. They are more or less asymmetric, tend to be ovate-lanceolate in form, with acute to blunt apices, and evenly serrate margins, the teeth being single, sharp-angular in some instances but rounded-mammillate in others, as in the figured specimen.

This species was originally compared with *Ulmus parvifolia* Jacquin, but the latter, although admittedly bearing some single-serrate leaves, has preponderantly double-serrate foliage. I have never seen a double-serrate leaf in *Zelkova hesperia*, though this could be possible, as it is rarely in the living species of *Zelkova*. However, the regular, slightly curving, but unbranched secondaries, with an exceptional secondary forking near the midrib, and the clear-cut regularity of the teeth, are features that distinguish these leaves as *Zelkova* and remove them from *Ulmus*.

The species differs from *Zelkova drymeja* at Florissant, Colo., chiefly in having broader variants among its leaves and in the teeth being more conspicuously rounded.

Occurrence: Oligocene. Gray Ranch (now McCullough), 11 miles east of Post, on Crooked River, Oreg.; collected by R. W. Brown.

Zelkova nervosa (Newberry) Brown, n. comb.

Planera nervosa Newberry (*42*), p. 508; *43*, p. 83, pl. 67, figs. 2, 3; Brown (*10*), p. 284, pl. 71, figs. 7–9; Brown (*11*), p. 56. [See synonymy.]
Myrica minuta Knowlton (*33*), p. 157, pl. 37, fig. 12; Brown (*11*), p. 54, pl. 9, figs. 1, 2. [See synonymy.]

In my discussions of the species here synonymized I referred to the possibility of their being *Zelkova*. Recent collections have yielded additional twigs bearing characteristic leaves and fruits that confirm the validity of the transfer to *Zelkova*.

These leaves are in general only slightly asymmetric, with occasional conspicuous exceptions. They are linear-ovate to elliptic in outline, the widest portion of the blade being at or just below the midpoint of the midrib. The teeth are single, serrate, sharp or rounded, receiving the slightly curved, unbranched secondary veins.

This species differs from *Zelkova drymeja* and *Z. hesperia* chiefly in having foliage that is notably more elliptic in outline.

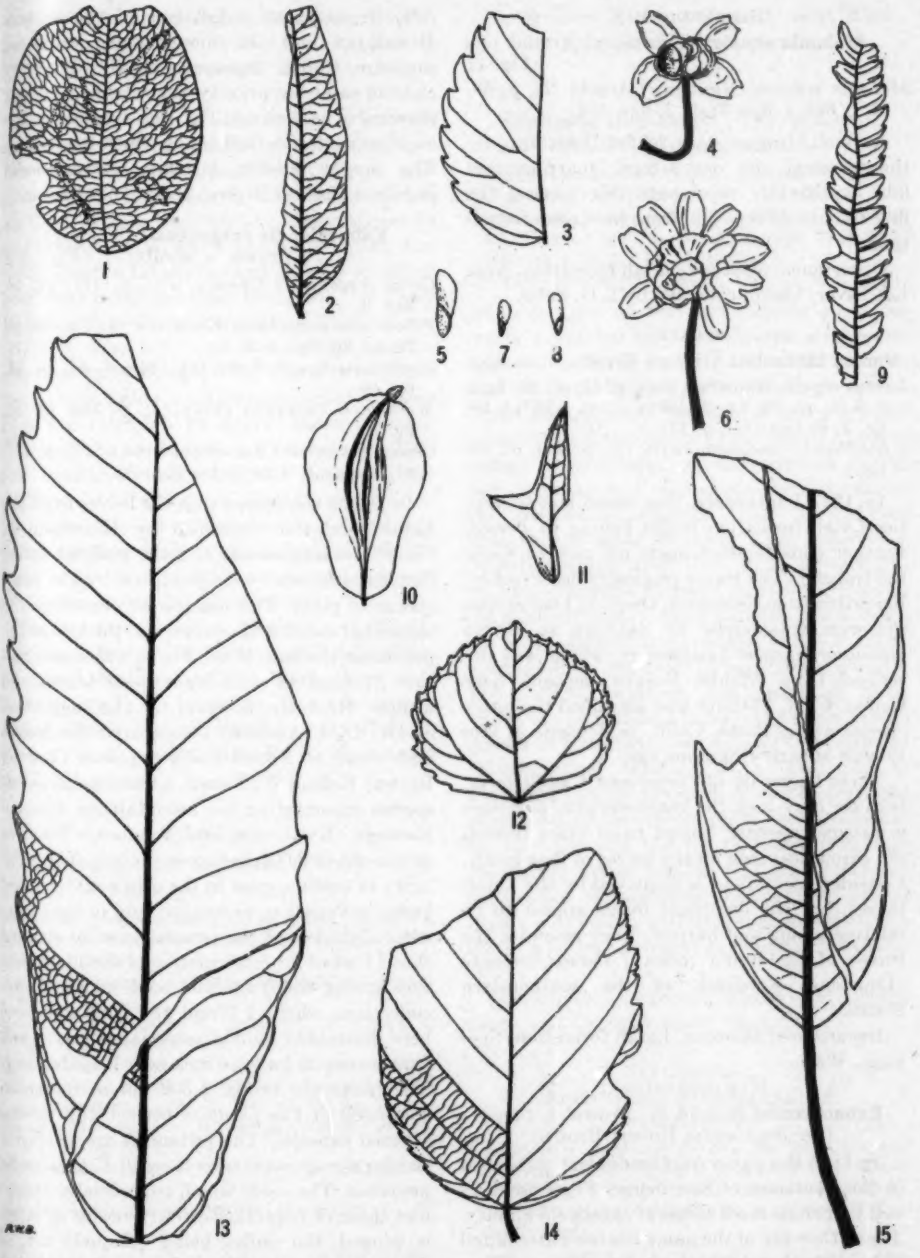
Occurrence: Eocene. Green River formation. At numerous localities in Colorado.

Zelkova ungeri Kovats

Zelkova ungeri Kovats. Hu and Chaney (*28*), p. 41, pl. 15, figs. 1, 3, 4; pl. 16, figs. 1, 3.
Carpinus mioturczaninowii Hu and Chaney (*28*), p. 33, pl. 9, fig. 2 [not other figures].
Acer miohenryi Hu and Chaney (*28*), p. 59, pl. 33, fig. 3c; pl. 34, fig. 2; pl. 35, fig. 2 [not other figures].

The large, rounded, mammillate, simple teeth, the generally unbranched secondaries, but with occasional forks starting well in toward the midrib, identify these leaves as *Zelkova*. They can be matched from almost any tree of *Zelkova serrata* Maximowicz.

Occurrence: Miocene. Shanwang, China.



FIGS. 1, 2.—*Koelreuteria mixta* (Lesquereux) Brown, n. comb. FIG. 3.—*Zelkova hesperia* Brown, n. sp. FIGS. 4–6.—*Exbucklandia oregonensis* (Chaney) Brown, n. comb. FIGS. 7, 8.—Seeds of *Liquidambar* sp. FIG. 9.—*Comptonia mississippiana* Brown, n. sp. FIG. 10.—*Halesia columbiana* Brown, n. sp. FIG. 11.—*Mahonia simplex* (Newberry) Arnold. FIG. 12.—*Populus lindgreni* Knowlton. FIG. 13.—*Quercus azelrodi* Brown, n. sp. FIG. 14.—*Betula taylorana* Brown, n. sp. FIG. 15.—*Rhododendron chaneyi* Brown, n. sp. All figures natural size.

BERBERIDACEAE

Mahonia simplex (Newberry) Arnold
Fig. 11

Mahonia simplex (Newberry) Arnold (*1*), p. 58, pl. 1, figs. 1–3, 6–7; pl. 2, figs. 1–2.

A small, fragmentary leaflet, bearing only the terminal and one lateral, sharp-pointed lobe, apparently represents this species, the first time to be reported from the Latah formation.

Occurrence: Miocene. Latah formation. Near Elk River, Idaho; collected by I. G. Sohn.

LAURACEAE

Persea lanceolata (Berry) Brown, n. comb.

Laurus similis Knowlton (*34*), p. 41, pl. 23, figs., 4, 5, 6; pl. 24, fig. 2; Berry (*4*) p. 259, pl. 58, fig. 2; Brown (*13*), p. 174.
Umbellularia lanceolata Berry (*4*), p. 260, pl. 59, fig. 1.

In 1937 I intimated that these leaves from the Latah formation might belong to *Persea*. Further consideration leads me now to make the transfer. The leaves originally described by Knowlton from Comstock, Oreg., as *Laurus similis* were transferred by Sanborn to *Persea pseudocarolinensis* Lesquereux, which was described from Middle Eocene deposits near Colfax, Calif. Potbury also identified the latter species at La Porte, Calif., in deposits of late Eocene or early Oligocene age.

These leaves do not represent *Umbellularia*, because they lack the characteristic, although sometimes obscure, paired basal veins (incipient primaries) seen on the leaves of that genus. Considerable variety is displayed by the Latah leaves, but the dominant forms appear to be relatively long and narrow. They resemble the leaves of the living redbay, *Persea borbonia* (Linnaeus) Sprengel, of the southeastern States.

Occurrence: Miocene. Latah formation. Spokane, Wash.

HAMAMELIDACEAE

Exbucklandia Roland W. Brown, n. name (for *Bucklandia* Robert Brown)

In 1825 the name *Bucklandia* was published in the *Tentamen* of Sternberg's *Flora der Vorwelt* to include fossil stems of cycadeoid affinity. The authorship of the name has been attributed to both Presl and Sternberg, but this is now immaterial. In 1832 Robert Brown used the name *Bucklandia* for a genus of the witchhazel family, Hamamelidaceae, represented by one species, *B. populnea*, a tall tree of the eastern Himalayas and the mountainous areas of southern China. Inasmuch as the 1825 cycadeoid name has priority, the witchhazel genus requires a new name. For this I propose *Exbucklandia*, the derivation of which is obvious. The single species becomes *Exbucklandia populnea* (Robert Brown) Roland W. Brown.

Exbucklandia oregonensis (Chaney) Brown, n. comb. Figs. 4–6

Cercis oregonensis Chaney (*19*), p. 177, pl. 16, figs. 3, 4.
Ficus? washingtonensis Knowlton (*34*), p. 40, pl. 25; pl. 26, figs. 1–3.
Meibomites lucens Knowlton (*34*), p. 44, pl. 28, fig. 10.
Meibomites knowltoni Berry (*4*), p. 253, pl. 56, fig. 7.
Cercis spokanensis Knowlton. Brown (*13*), p. 177, pl. 54, figs. 8, 9 [not other figures].

In 1937 I considered that the leaves from the Latah formation described by Knowlton as *Ficus? washingtonensis* and the pods he called *Cercis spokanensis* were produced by the same species of plant. This opinion was based on the somewhat swollen appearance of the top of the petiole at the base of the blade, which is a feature common to most leguminous leaves and leaflets. Recently, however, at the suggestion of Dr. D. I. Axelrod, I compared the leaves with those of *Exbucklandia populnea* (Robert Brown) Roland W. Brown, a hamamelidaceous species inhabitating the mountainous areas of Kwangsi, Kwantung, and Yunnan, China, at elevations of 5,000 feet, more or less. The similarity in outline, even to the occasional pointed lobes, in venation, in texture, and in the somewhat alate top of the petiole, were so striking that I looked for confirmation of the identification among the fruits and seeds in the Latah collections where I found the fruit and seed here illustrated. Similar associated leaves and fruits occur on Layng Creek near Rujada, Oreg. The fruits are heads, 1.5–2 cm in diameter, composed of five or more perfect and several aborted capsules. The peduncles are relatively slender as compared with those of *Exbucklandia populnea*. The seed, which superficially resembles those of *Liquidambar* but is twice as large, is winged, the nutlet being obliquely set, of about the same length as the wing, rounded at the proximal end and sharp-pointed at the distal end, thus presenting a somewhat triangular appearance. The wing is not divided lengthwise

by a conspicuous line or vein as in *Liquidambar*, but this feature may be obscure or absent in fossil seeds of *Liquidambar*, as illustrated in Figs. 7, 8.

This disposition of the foliage of *Cercis oregonensis* Chaney and *Ficus? washingtonensis* Knowlton leaves the pods called *Cercis spokanensis* Knowlton as originally described but does not explain their affinity. They appear to be too large, thick, and blunt for acceptance as *Cercis*. Somewhat similar and perhaps identical pods were described from Bridgeton, N. J., by Hollick (*26*, p. 49) as *Mezoneurum bridgetonense* (pl. 258, figs. 1–7) and *Lonchocarpus novaecaesareae* (pl. 259, figs. 6–8). These two species are, in my opinion, a single species, but whether they are referable to either *Mezoneurum* or *Lonchocarpus* remains to be determined. Hollick tentatively regarded the Bridgeton deposits as late Tertiary or Pleistocene. The Latah pods may be related to the foliage now called *Sophora spokanensis* Knowlton, but the latter may be a mixture of several legumes which cannot yet be differentiated.

Occurrence: Miocene. Eagle Creek formation, near Bonneville, Oreg. Latah formation, brickyard locality, Spokane, Wash. (Figs. 4, 5) collected by E. E. Alexander. One mile east of Layng Creek Ranger Station, near Rujada, Oreg. (Fig. 6); collected by R. W. Brown and A. G. Simson.

ROSACEAE

Amelanchier couleeana (Berry) Brown, n. comb.

Phyllites couleeanus Berry (*6*), p. 42, pl. 13, fig. 12.
Amelanchier scudderi Cockerell. Berry (*4*), p. 252, pl. 55, fig. 4.
Amelanchier grayi Chaney. MacGinitie (*40*), p. 58.
Amelanchier magnifolia Arnold (*2*), p. 89, pl. 4, figs. 1, 4; text figs. 2, 3.
Amelanchier dignatus (Knowlton) Brown (*12*), p. 577 [not pl. 69, figs. 5, 6, which need reidentification]; Brown (*13*), p. 176, pl. 53, fig. 11.
Amelanchier dignata (Knowlton) Smith (*47*), p. 514, pl. 13, fig. 2.
Amelanchier elliptica Smith (*47*), p. 514, pl. 13, fig. 1.
Amelanchier subserrata Smith (*47*), p. 514, pl. 13, fig. 7.

In 1935 I erred in transferring *Celastrus dignatus* Knowlton (*30*, p. 71, pl. 11, fig. 5) to *Amelanchier*, later finding that it is a specimen of *Zelkova oregoniana* (Knowlton) Brown.

Occurrence: Miocene. Grand Coulee, Wash., and other localities in adjacent states.

FABACEAE

Cladrastis oregonensis (Knowlton and Cockerell) Brown, n. comb.

Fraxinus oregonensis Knowlton and Cockerell. Knowlton (*32*), p. 296.
Umbellularia oregonensis (Knowlton and Cockerell) Chaney (*20*), p. 60, pl. 1, figs. 1, 3, 5, 7; Chaney (*21*), p. 117, pl. 14, fig. 2.
Cladrastis oregonensis Brown (*14*), p. 415, fig. 1.

Comparison of the fossil leaves most recently identified as *Umbellularia oregonensis* with similar living leaves of *Umbellularia* shows that the fossils lack a significant feature of most *Umbellularia* leaves, the pair of obscure basal primaries. Furthermore, in the fossils the secondary veins display constant smooth curvation, whereas in *Umbellularia* the secondaries are somewhat irregular, and are almost straight for some distance after emergence from the midrib until they curve upward abruptly toward the adjacent secondary. Finally, the relatively short, thick petioles of the fossils are finely striated transversely, which is an almost infallible indicator of leguminous affinity. The outline, venation, and petiole of these leaves can be matched in leaves of some Asiatic species of *Cladrastis*, particularly *C. platycarpa* (Maximowicz) Makino. As a fossil pod of *Cladrastis* has already been described from the same locality the presumption seems reasonable that the pod and leaves confirm one another. It is further possible that the small fossil pods called *Micropodium ovatum* (Lesquereux) Brown also belong with this species or that the leaves represent two species not readily separable.

Occurrence: Oligocene shales on Bridge Creek and Crooked River, Oreg.

SAPINDACEAE

Koelreuteria miointegrifoliola Hu and Chaney

Koelreuteria miointegrifoliola Hu and Chaney (*28*), p. 64, pl. 38, fig. 1 [not pl. 38, fig. 3, nor pl. 39, fig. 3 (which is identical with pl. 8, fig. 5), both being referable to a species of Juglandaceae].

Comparison of the leaflets assigned to this species with the leaflet of *Koelreuteria integrifoliola* Merrill (pl. 39, fig. 2), although suggesting some similarities, shows that they differ

in three important particulars: the marginal teeth are sharp serrate-dentate rather than blunt and crenate; they lack petioles; and they have no prominent intersecondaries. The leaflets, therefore, are not referable to *Koelreuteria*, but to one of the juglandaceous species of the same flora.

With the elimination of these leaflets only the capsule now represents *Koelreuteria miointegrifoliola*. Speculation, however, prompts an inspection of the remainder of the flora for possibilities of *Koelreuteria* foliage. Other pinnately compound-leaved species described by Hu and Chaney are: *Ailanthus youngi*, *Cedrela bienensis*, *Pistacia miochinensis*, and *Rhus miosuccedanea*. Of these, *Cedrela bienensis* is removed by transfer (see *Pseudolarix*) to other genera. The leaflets and fragmentary seed (pl. 30, figs. 4, 5, 8, 9), referred to *Ailanthus youngi*, are mixed. The illustration reveals nothing conclusive as to the correct identity of the seed. The leaflet (fig. 4), with its numerous, sharp, serrate teeth, certainly does not represent *Ailanthus*. The remaining leaflets, together with those of *Pistacia miochinensis* and *Rhus miosuccedanea* are, therefore, under suspicion of harboring among their number some that belong to *Koelreuteria*, but without having the actual specimens for comparison with living material I hesitate to make any specific transfers.

Occurrence: Miocene. Shanwang, China.

Koelreuteria reticulata (Ettingshausen) Brown, n. comb.

Dalbergia reticulata Ettingshausen (*23*), p. 37, pl. 4, fig. 5 [not fig. 6, which is *Copaifera longestipitata* Kovats].
Tmesipteris reticulata (Ettingshausen) Hollick (*25*), p. 256.
Phyllites reticulatus (Ettingshausen) Florin (*24*), p. 255.
Ptelea macroptera Kovats (*35*), p. 51, pl. 1, fig. 2.
Koelreuteria macroptera (Kovats) Edwards (*22*), p. 111.

Ettingshausen's specimen is a fragmentary valve without evidence of seeds, but the reticulations are fairly clear. Kovats's specimen is a large, fragmentary valve with the impressions of two rounded seeds, but the reticulations are obscure. As both specimens came from the same strata near Tallya in northeastern Hungary, I see no practical reason for regarding them as different species. Whether this species should also include specimens from the Miocene of Switzerland and Bohemia, erroneously identified by Heer and Brabenec, respectively, as *Salvinia reticulata* (Ettingshausen) Heer, must depend on the finding of better material. What reported leaflets should be assigned to this species is also debatable. Ettingshausen (*23*, p. 36, pl. 2, fig. 10) identified as *Rhus paulliniaefolia* what are apparently the apical three leaflets of a compound leaf. These leaflets came from the same locality as the valves here referred to *Koelreuteria reticulata* and could, by comparison with the leaflets of some living species, have come from a species of *Koelreuteria*. However, caution is indicated because Ettingshausen also reported from the same strata one leaflet referred to *Sapindus falcifolius* Al Braun (p. 33, pl. 4, fig. 1) and another to *S. hazlinskyi* Ettingshausen (p. 33, pl. 4, fig. 2 both of which could also be duplicated from living species of *Koelreuteria*.

Occurrence: Miocene strata near Tallya, Hungary.

Koelreuteria nigricans (Lesquereux) Brown, n. comb.

Myrica nigricans Lesquereux (*37*), p. 132, pl. 17, figs. 9–12.
Rhus nigricans (Lesquereux) Knowlton (*33*), p. 168.
Myrica ludwigii Schimper. Lesquereux (*37*), p. 133, pl. 65, fig. 9.
Myrica undulata? Heer. Lesquereux (*37*), p. 131, pl. 17, figs. 6, 7 [not fig. 8, which remains. It is from Elko, Nev., not Green River, Wyo.]
Myrica alkalina Lesquereux (*39*), p. 149, pl. 45A, figs. 10–15; Brown (*10*), p. 283, pl. 71, figs. 2, 3.
Myrica zachariensis Saporta. Lesquereux (*39*), p. 146, pl. 45A, figs. 6–9 [not pl. 25, fig. 5, which is a Florissant specimen].
Myrica sp. Knowlton (*33*), p. 157, pl. 37, fig. 2.
Planera variabilis Newberry (*43*), p. 83, pl. 66, fig. 7 [not figs. 5, 6].
Rhus variabilis (Newberry) Knowlton (*33*), p. 167; Brown (*11*), p. 59, pl. 11, figs. 1–4.
Rhus myricoides Knowlton (*33*), p. 188, pl. 37, figs. 9–11; Brown (*10*), p. 287, pl. 73, fig. 9.
Comptonia insignis (Lesquereux) Cockerell. Brown (*11*), p. 54.
Staphylea viridifluminis Hollick (*27*), p. 96, pl. 2, fig. 3.
Koelreuteria viridifluminis (Hollick) Brown (*11*), p. 62, pl. 10, fig. 10; Brown (*17*), p. 865, fig. 1 (N, O).

In my previous publications on the flora from the Green River formation I have repeatedly suggested the reference to *Koelreuteria* of most of the species here synonymized. The

aggregation is diverse, but I see no escape, because I find abundant intergradations. The leaflets now assigned to *Koelreuteria nigricans* are distinguished by being petiolulate and generally, but not always, elliptic in outline with the widest part of the blade midway between base and apex, whereas the leaflets of *Rhus* are nearly always sessile with a lanceolate to ovate-lanceolate outline, except in *R. copallina* Linnaeus, whose leaflets may also be elliptic in outline, but the rachis is more or less alate.

The valves of *Koelreuteria nigricans* are elongated elliptical. One figured specimen (Brown, *11*, pl. 10, fig. 10) shows the broad placental flange to which the seed was attached.

Occurrence: Middle Eocene. Green River formation. Numerous localities in Colorado and Wyoming. Lesquereux's locality citation for *Myrica undulata?* Heer (figs. 6, 7) as Elko, Nev., is incorrect and should be "near Green River Station, Wyo."

Koelreuteria mixta (Lesquereux) Brown, n. comb. Figs. 1, 2

Rhus mixta Lesquereux (*38*), p. 30, pl. 9, fig. 13; MacGinitie (*41*), p. 142, pl. 35, figs. 1, 4; pl. 36, fig. 1.

Soon after MacGinitie's study of the Middle Eocene Chalk Bluffs flora of the Sierra Nevada had been published I discovered among the National Museum collections from Independence Hill, Calif., the capsular valve of *Koelreuteria* here figured. It compares in size with the largest of *Koelreuteria alleni* (Lesquereux) Edwards from the lake beds at Florissant, Colo., but the reticulate venation has a tendency toward elongation, whereas in *K. alleni* the reticulations are rather evenly polygonal to squarish. No impressions of seeds are evident.

Although MacGinitie found a favorable comparison between the leaflets of *Rhus mixta* and leaflets of some living species of *Rhus*, there is at least one suspicious difference, namely, that the fossil leaflets are distinctly petiolulate (see MacGinitie's pl. 35, fig. 1; pl. 36, fig. 1), whereas the leaflets of *Rhus* are generally sessile or nearly so. I am therefore swayed to believe that these leaflets represent *Koelreuteria*. Not all the leaflets are toothed, some, as that figured, being entire. These leaflets resemble rather closely some of *Koelreuteria nigricans* (Lesquereux) Brown of the Green River formation in Colorado and Wyoming. MacGinitie synonymized *Astronium oregonum* Chaney and Sanborn with *Rhus mixta*, but I hesitate to do so, inasmuch as no capsules of *Koelreuteria* have been taken, or at least not reported, from the Goshen and Comstock deposits.

Occurrence: Middle Eocene strata at You Bet (Fig. 2) and Independence Hill (Fig. 1), near Colfax, Calif.; collected by R. W. Brown and Cooper Curtice, respectively.

STYRACACEAE

Halesia columbiana Brown, n. sp. Fig. 10

Fruit 3 cm long, two-winged, oblong in outline, tipped by the blunt remains of the style. Peduncle broken. This fruit resembles closely those of the silverbell tree, *Halesia diptera* Ellis. The latter is a small tree that inhabits wet woods and borders of swamps in the southeastern United States. I have seen no leaves in the Latah collections that could be assigned beyond doubt to this species.

Occurrence: Miocene. Latah formation. Brickyard locality, Spokane, Wash.; collected by R. W. Brown.

ERICACEAE

Gaultheria pacifica Brown, n. sp.

Arbutus matthesi Chaney. Brown (*13*), p. 184, pl. 59, figs. 5, 6 [not fig. 1, which is transferred to *A. idahoensis* (Knowlton) Brown].

Soon after I identified these leaves from the Latah formation as *Arbutus matthesi* Chaney, originally described from Oligocene strata on Crooked River, Oreg., I realized that I had made a mistake. They compare much more favorably with the leaves of *Gaultheria* than with those of *Arbutus*. The few, widely spaced, long, looped secondaries that curve upward toward the acute apex, the numerous, minute sharp, serrate, marginal teeth, and the rounded to cordate bases are notable identifying features. Among the 90 species of *Gaultheria* whose distribution is in the warmer regions of the Americas, Asia, and Australia, the closest living match for the fossils seems to be *G. shallon* Pursh, of the Pacific coastal region. The presence of *G. pacifica* in the Latah flora, as judged by the climatic requirements of *G. shallon*, emphasizes the relatively mild, moist character of the Latah environment. This species appears to be the first recognized fossil *Gaultheria* from the Western Hemisphere. Several species based,

in my opinion, on somewhat dubious evidence, as judged by the illustrations, have been described from European localities.

Occurrence: Miocene. Latah formation, Brickyard locality, Spokane, Wash.

Rhododendron chaneyi Brown, n. sp.
Fig. 15

Leaves 15–20 cm long, lanceolate to elliptic in outline, with cuneate to rounded base, the form of the apex being unknown. Margin entire, heavy. Petiole 3.5 cm long, stout. Midrib stout, straight to slightly curved; secondaries evenly spaced, camptodrome, smooth to somewhat irregular, with short intersecondaries. Five incomplete specimens represent this species.

These leaves are smaller, slenderer, less oblanceolate in outline, and thinner in texture than the leaves of *Rhododendron maximum* Linnaeus of eastern North America. The species, however, was probably adapted to climatic conditions similar to those under which the latter thrives. Most of the fossil rhododendrons so far described from North America leave considerable to be desired as regards convincing identity. Probably all can be referred readily to other genera.

I name this species for Dr. Ralph W. Chaney, who has contributed much to the progress of paleobotany in the United States.

Occurrence: Oligocene. About 11 miles east of Post, on Crooked River, Oreg., collected by R. W. Brown.

ADDITIONAL CHANGES

Arbutus matthesi Chaney. Brown (*13*, p. 184, pl. 59, fig. 1) = *Arbutus idahoensis* (Knowlton) Brown.

Arisaema hesperia Knowlton (*34*), p. 29, pl. 10, fig. 1 = *Liquidambar pachyphyllum* Knowlton. This specimen is a much worn sweetgum fruit as can be seen by comparison with the better preserved specimen (Fig. 10) shown on the same plate but identified by Knowlton as *Liquidambar*.

Cebatha heteromorpha (Knowlton) Berry (*6*), p. 37 = *Cocculus heteromorpha* (Knowlton) Brown, n. comb. *Coccuius* is the currently accepted name for this genus.

Cedrela bienensis Hu and Chaney (*28*), p. 54, pl. 30, fig. 2 = *Rhus miosuccedanea* Hu and Chaney.

Cedrela? pteriformis (Berry) Brown. Smith (*47*), p. 516, pl. 14, fig. 2 = *Quercus simulata* Knowlton.

Celastrus dignatus Knowlton (*30*), p. 71, pl. 11, fig. 5 = *Zelkova oregoniana* (Knowlton) Brown.

Cercocarpus praeledifolius Berry. Brown (*13*), p. 177, pl. 56, fig. 13 = unidentified leaf. I find, on recomparison, that this leaf is not the same as the type, and there is considerable doubt that the latter represents *Cercocarpus*.

Engelhardtia tuckeri Smith (*45*), p. 226, pl. 1, fig. 4 = *Acer* sp. This is a fragmentary three-lobed leaf. In 1941 I collected an almost exactly identical specimen at the same Hog Creek, Idaho, locality, but it is somewhat better preserved and has several teeth on the lobes.

Glyptostrobus? staminate aments. Berry (*4*), p. 239, pl. 63, fig. 1 = *Taxodium dubium* (Sternberg) Heer.

Hicoria washingtoniana Berry (*6*), p. 35, pl. 11, fig. 4 = *Magnolia dayana* Cockerell. The margins of this broken leaf and its counterpart are entire, not crenate as described and illustrated.

Limnanthemum circularis (Chaney) Brown (*16*), p. 352 = *Nymphoides circularis* (Chaney) Brown, n. comb. The currently accepted name for *Limnanthemum* is *Nymphoides* and the genus is considered as belonging to the Gentianaceae rather than the Menyanthaceae.

Liquidambar europaeum Al. Braun. Newberry (*43*), p. 100, pl. 47, fig. 3 = *Sparganium* sp. Although *Liquidambar* is present in the flora from the shales on Bridge Creek, Oreg., this fruiting head, originally attributed to *Liquidambar*, has single-beaked carpels, whereas those of *Liquidambar* are two-beaked. Fossil fruits of *Liquidambar* are coarser in appearance than those referred to *Sparganium* and usually display several deep cavities.

Liquidambar fruit. Knowlton (*34*), p. 42, pl. 10, fig. 10 = *Liquidambar pachyphyllum* Knowlton.

Magnolia spectabilis Knowlton. Berry (*8*), p. 93, fig. 1 = *Nyssa hesperia* Berry.

Nyssa knowltoni Berry. Brown (*13*), p. 184, pl. 62, figs. 1–3 = *Nyssa hesperia* Berry.

Nyssa knowltoni Berry (*4*), p. 261, pl. 59, fig. 7 = *Ptelea miocenica* Berry. Without seeing the specimens themselves I hesitate to pass judgment on the identity of the leaves identified as

Nyssa knowltoni by Arnold (*2*, p. 97, pl. 8, figs. 1, 5).

Populus, pistillate ament. Berry (*4*), p. 243, pl. 63, fig. 7 = *Taxodium dubium* (Sternberg) Heer.

Quercus deflexiloba Smith (*47*), p. 506, pl. 8, fig. 4 = *Quercus pseudolyrata* Lesquereux.

Quercus merriami Knowlton (*34*), p. 35, pl. 19, figs. 4, 5 = *Quercus payettensis* Knowlton.

Quercus spokanensis gracilis Berry (*7*), p. 110, pl. 20, figs. 4, 5 = *Quercus coprinus* Smith. The specimens described by Berry, when compared with the specimen described by Knowlton as *Quercus spokanensis*, which is a *Castanea*, are found to be distinct, warranting the omission of the term *spokanensis*. As *gracilis* was once used by Newberry for a species of *Quercus*, which is now a synonym of *Dryophyllum subfalcatum* Lesquereux, the term *coprinus* becomes valid.

Quercus ursina Knowlton. Berry (*8*), p. 92, fig. 8 = *Quercus pseudolyrata* Lesquereux. This specimen, as well as a number of others that are more typical of the species, comes from Grand Coulee, Wash. They are the first reported specimens of this species from the Latah formation.

Rhamnus idahoensis Brown (*13*), p. 181, pl. 56, fig. 4 = *Viburnum lantanafolium* Berry.

Rhododendron idahoensis Smith (*46*), p. 480, pl. 13, figs. 6, 10 = *Castanopsis perplexa* (Knowlton) Brown.

Salix florissanti Knowlton and Cockerell. Berry (*4*), p. 242, pl. 64, fig. 16 = *Salix hesperia* (Knowlton) Condit.

Salix spokanensis (Berry) Brown (*13*), p. 168, pl. 46, fig. 8 = *Sophora spokanensis* Knowlton. A reexamination of the petiole of this specimen shows transverse striations characteristic of most leguminous leaves and leaflets. Under occurrence and in the plate legend this specimen was erroneously listed as from Idaho City, Idaho. It is from Spokane, Wash. The specimens remaining in *Salix spokanensis* as given in my 1937 synonymy perhaps represent a mixture. Some seem to be small leaves of *Salix hesperia* (Knowlton) Condit. Others may not belong to *Salix*. However, I am not yet prepared to resolve this difficulty.

Sapindus idahoensis Smith (*47*), p. 518, pl. 13, fig. 6 = *Quercus simulata* Knowlton. The long petiole of this leaf removes the specimen from *Sapindus*.

Sequoia langsdorfi (Brongniart) Heer. Knowlton (*33*), p. 26, pl. 9, figs. 3–6; Berry (*7*), p. 104 = *Taxodium dubium* (Sternberg) Heer. All the material from the Latah formation in the National Museum collections, heretofore assigned to *Sequoia langsdorfi*, has stalked leaves without the prominent, twisted, decurrent bases characteristic of *Sequoia*.

Smilax lamarensis Knowlton. Berry (*4*), p. 240, pl. 63, fig. 15; Berry (*7*), p. 105, pl. 19, fig. 7 = *Smilax magna* Chaney. Although two species of *Smilax* could very well have been present in the Latah flora, the specimens so far reported could equally well have been produced by the same Miocene species.

Theobroma fossilium Berry (*5*), p. 8, pl. 1, figs. 13, 14. This specimen, considered by Berry to be the first fossil record of *Theobroma*, is a section of the forepart of a reptilian jaw. Berry mistook the bony structure for the pulp, and the teeth for the seeds of a chocolate-bean pod. Although described among Tertiary plants, the specimen, as stated by Berry, came from near Leiva, Department of Boyaca, Colombia, where Cretaceous strata crop out.

Umbellularia dayana (Knowlton) Berry. Brown (*13*), p. 174 [not pl. 52, fig. 13, which remains unidentified], all items except the original *Salix dayana* from the Mascall formation = *Cedrela pteraformis* (Berry) Brown.

Undetermined leaf. Brown (*13*), p. 186, pl. 53, fig. 13 = *Salix hesperia* (Knowlton) Condit.

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ETHNOLOGY.—*Ethnoherpetology of the Catawba and Cherokee Indians.*[1]

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Interest along lines of study in the shadowy historical background out of which the natural sciences emerge from the classical age of thought has scarcely yet gone far enough to make place for the present paper. Yet to venture ahead of time because it is important to record data on the animal lore of preliterate peoples leads to inquiry into newly opened fields of ethnozoology. Like the now-recognized subject of ethnobotany, the scope of ethnozoology will deepen and broaden as it assumes a place in the curriculum of research. Ethnoherpetology indeed offers unlimited prospects for exploration into native cultures far and wide, beginning with study in the environs of Indian tribes in the Americas.

No attention has been given so far to a treatment of native faunal lore among Indians of North America which might suggest that a rudimentary native system of zoological taxonomy existed. It might have been assumed that at least some beginnings of such a system would exist among tribes of mankind so familiar with animal appearances and habits.

The purpose of the present short paper, then, is to present hitherto unrecorded data on reptilian nomenclature of two unrelated tribal groups of the southeastern United States in order to illustrate the character of such an arrangement of reptiles based upon observation of descriptive details and habits.[2]

The two tribes from which the data here presented have been taken are the Catawba of the piedmont in northwestern South Carolina, near the border of the Upper and Lower Austral Zones, and the Cherokee of the mountains of western North Carolina, in the Transitional Zone. The reptilian biota of these regions differs considerably as the listing shows. The linguistic and cultural backgrounds of the two peoples are decidedly unrelated; the Catawba constitute a southeastern branch of the Siouan linguistic family; the Cherokee fall into the Iroquoian linguistic stock.

The Catawba material, I may say, is the accumulation of facts relating to reptiles and amphibians recorded during some years of continued but intermittent field work with the last four Indians who used the Catawba language. Chief Sam Blue was the principal source consulted in the revision of name identities of reptiles written down from dictation of older informants now deceased. A recent return-trip to the region gave an opportunity to review and revise the data previously obtained and to prepare

[1] Received April 26, 1946.

[2] Some of these ideas were touched upon in a short article presenting data on northeastern Algonkian reptile identities and reptile lore (F. G. SPECK, *Reptile lore of the northern Indians*, Journ. Amer. Folklore **36** (141). July-Sept. 1923). See also F. G. SPECK and E. S. DODGE, *Amphibian and reptile lore of the Six Nations Cayuga* (Journ. Amer. Folklore **58** (230). 1945).

In the preface to K. P. SCHMIDT and D. D. DAVIS'S *Field book of snakes of the United States and Canada*, p. XI, 1941, the authors review the present situation in respect to reptile study: "In the past, study of American snakes has dealt chiefly with taxonomic problems. We believe that as purely taxonomic problems become less productive, interest will gradually shift to topics of broader biological interest. With this in mind, we have placed particular emphasis on life history, habits, behavior, and ecology. Description has been restricted to what is necessary for identification of specimens." Here also the subject of ethnoherpetology is unsensed as a possible line of investigation.

the list for final publication.[3] It is hardly possible now that more complete information along these lines can be expected, since the language and culture of the Catawba have become obsolete.

Departmental cooperation in projects of research in the Cherokee Nation resulted in the Cherokee material which is prepared from notes made in the field on the same occasions while collecting culture elements of the Eastern Cherokee. A number of informants were consulted, especially West Long of the Big Cove settlement. The notes have been extended by additions contributed by John G. Witthoft, University of Pennsylvania, who accompanied me on several trips of investigation.

An element of classification is evident in the material. Aside from the use of descriptive terms to denote the creatures some terms refer to ideas of pure folklore. But some remark may be made concerning the sources of reptile and amphibian names, both scientific and popular, in the European tradition of taxonomy. The naming system for reptiles (and the same may be said for other animal forms) among Catawba and Cherokee reminds the nature historian of the technical naming principles established by Linnaeus and others who long ago set the tradition of taxonomy by using Greek and Latin definitives in zoological classification.[4] The correspondence, indeed, between science and folklore in the naming of animals seldom evokes even passing thought among those who habitually use them, for most of us have blindly taught ourselves to take our own word traditions for granted in the quaint logic of science without seeking for their derivations.

In Indian systems of animal classification we find that groupings are usually determined by external features and habits of motion rather than by morphological distinctions. So the Catawba would insist that the whale is a fish as firmly as the biologist would deny it.

The tribal sources of observation from which nomenclature is drawn are only occasionally alike; the differences are due to differences in the cultures of Catawba and Cherokee, ethnic groups possessing unrelated languages and legendary heritages, and to their inhabiting different biotic zones.

CATAWBA REPTILE LIST

I. The Snakes

An essentially simple twofold classification of reptiles seems to have been achieved in the thought process of the Catawba which resulted in the naming of forms by groups embraced under classifying denominatives. Roughly compared with the taxonomy of biology one group of the class Reptilia may be correlated with the subclass Chelonia, designated in Catawba by the term kayá ("turtle" in free rendering), another with the subclass Crocodilia by the term hi·, "alligator." The category of reptiles corresponding to the order Ophidia we find de-

[3] Acknowledgements are made to the Faculty Research Fund, University of Pennsylvania (Grant 570), and the Field Research Fund in Anthropology for 1945, for support of the undertaking.

[4] Compare, for instance, the following scientific reptile designations, translated from Greek and Latin into English, with the Indian terms in the lists: *Crotalus horridus*, "rattler bristling"; *Sistrurus miliarius*, "rattletail containing a thousand"; *Agkistrodon piscivorus*, "fish-hook tooth fisheater"; *Heterodon contortrix*, "different-tooth twister"; *Coluber constrictor*, "serpent squeezer"; *Diadophis punctatus*, "crowned-snake spotted"; *Lampropeltis getulus*, "shining-shield African"; *Masticophis flagellum*, "whip-snake whip"; *Elaphe guttata*, "deer spotted"; *Liopeltis vernalis*, "smooth-shield springtime"; *Opheodrys aestivus*, "tree-snake summertime"; *Thamnophis*, "thicket-snake"; *Eutaenia*, "beautiful band"; *Natrix sipedon*, "swimmer tube-tooth"; *Cemophora coccinea*, "muzzle-bearing scarlet."

I must acknowledge the aid given me in tracing sources and meanings of these terms by Dr. W. W. Hyde and Miss Anna K. Stimson, of the University of Pennsylvania. I have also made use of E. C. JAEGER, *A dictionary of Greek and Latin combining forms used in zoölogical names*, Baltimore, 1931, and D. S. JORDAN, *Manual of the vertebrate animals*, Yonkers-on-Hudson, 1929, for the same purpose.

To Dr. R. M. Stabler, Department of Zoölogy, University of Pennsylvania, I am indebted for critical reading of the material as presented and for his comments on its arrangement. By his advice as a taxonomist I have not included names of subspecies or authors of descriptions in the listings of identities. The nomenclature follows L. STEJNEGER and T. BARBOUR, *A check list of North American amphibians and reptiles*, Cambridge, 1933.

noted by the term ya, "snake" in general. (Without digressing from the topic of reptiles at this point, it may be noted incidentally that group designations include other classes of the faunal realm, tcų, "insect"; yi·, "fish"; kutcín, "bird"; and so on—all generalizing collective terms.)

The Catawba binomial system of phylogeny then drops to a designation for species by the use of specific modifiers of the generic term ya, as the following list will show. One might add that a possible recognition of subspecific characters is vouched for by use of the modifiers tų, "little," and tərό, "big," as suffixes to some specific names.

The list of 17 specific snake names known to informants is as follows[5]:

1. ya swą'ʔ, "snake chief," king, or greatest, rattlesnake (*Crotalus horridus*). The snake of paramount importance in the nature lore of the Catawba, and the Creeks as well, who denote it similarly (tcít·o mi'k·o, "snake chief").

2. ya mantúgrere, "snake home in ground," ground rattlesnake (*Sistrurus miliarius*).

3. ya pa'kata tcesá, "snake narrow-necked," copperhead (*Agkistrodon mokasen*).

4. ya yámure, "snake staying in water," water moccasin (*Agkistrodon piscivorus*).

5. ya hi· ska' kwątcere, "snake head spreads," hog-nose snake (*Heterodon contortrix*). ya wį· túpʿ, "snake spotted."

6. ya wáktciye, "snake black," black racer (*Coluber constrictor*).

7. ya tų wáktciye, "snake little black," ringnecked snake (*Diadophis punctatus*). The Catawba regard this reptile as an immature form of the black racer.

8. ya migráhərе, "snake chief," king snake (*Lampropeltis getulus*). The specific term is a synonym of the term given for rattlesnake. To the informant this is a "boss of snakes." The term ya suré, "snake wild," was also given for this animal by Sally (Brown) Gordon in 1928.

9. ya tiríre hɑ, "snake thunder present," milk snake (*Lampropeltis triangulum*). The identification of this species was uncertain to the informant.

10. ya yispá hę, "snake whip," coachwhip (*Masticophis flagellum*). The informant, Sam Blue, had heard that this creature could "stand up and whistle!"

11. ya nəmotúksa hę, "snake in ground stays," corn snake (*Elaphe guttata*).

12. ya tų nəmómusàre, "snake small in ground stays" (*Cemophora coccinea*).

13. ya wədésəna, "snake cow male" (or "bull snake" locally), gray rat snake (*Elaphe obsoleta confinis*). This form was not well known to the informant.

14. ya waŋká', "snake green," rough green snake (*Opheodrys aestivus*). ya ya'ɑ', "snake (pertaining to) woman." The second name was obtained from Margaret Brown in 1920.

15. ya yəmaterá, "snake garter," garter snake (*Thamnophis sirtalis*). The name applied to this form is manifestly of local English origin.

16. ya yąyamǫmúre, "snake in water lies" (*Natrix sipedon*).

17. ya yątce"mowàne, "snake in branch (creek) stays," queen snake or leather snake (*Natrix septemvittata*).

OTHER CREATURES CLASSIFIED AS SNAKES BY THE CATAWBA

1. ya kat'k'at'hərе, "snake jointed," glass snake (*Ophisaurus ventralis*). The modifier here is equivalent to "breaks into pieces." The "glass snake" is included in the list because of its snakelike character in Catawba esteem. It was not familiarly known to the informant who had encountered it only rarely. Said he, "Unless the pieces of its body are thrown into the river or burned, it will come alive again."

2. ya ciyé, "snake (in) mud," eel.

An attempt to identify other species known to literature of the region did not yield results with Indians questioned even with the help of the color plates and descriptions of appearance and habits.

[5] Herpetological identification was checked by use of excellent color plates in *The snakes of Maryland*, H. A. Kelley, A. W. Davis, H. C. Robertson, The Natural History Society of Maryland, Baltimore, 1936.

The symbols used in writing native terms in both languages of the notations are those customarily adopted by students of American linguistics. It may be noted for the convenience of those who are not concerned with details of phonetic transcription that the following letters differ from their use in English orthography, their equivalents being: *c* for English *sh*, *ɑ* (Greek alpha) for the *u* sound of English *but*, *ə* (inverted *e*) for the almost silent *e* in English *her*, a cedilla beneath a vowel to denote nasalization, the symbol ʔ for the glottal stop, ' to indicate an aspiration after a vowel or consonant, and the raised period to show lengthening of vowel. *ɔ* (reversed *c*) is used in Cherokee to denote *aw* as in English *law*.

REPTILES IN CATAWBA FOLKLORE[6]

Snake lore among the Catawba includes reference to the fabled hoop snake (ya tərɬ tərɬʔ hərə, "snake rolling"). Chief Sam Blue when questioned about the creature claimed to have seen it himself, and he said it had a brownish color. The legend of its existence is evidently one derived from white neighbors with whom the Indians have been associated for over a century.

The folklore of reptiles is unduly meager in the surviving body of tradition among the Catawba. Fables relate how a monster serpent dwelt in a turgid eddy of the Catawba River near one of the ancient villages. The serpent killed people by sucking blood from their necks or from under their arms. Another child-killing snake monster of the river constricted its victim. The symbolism of the snake in tribal tradition is that of enmity, and the people usually kill snakes for this reason when they are encountered. The poisonous species are categorically denoted by the term ya sigrʃ, "snake mean, polluted, unfit, spoiled, dirty," according to the divergently "unfavorable" meaning indicated by the adjective modifier.

Several snake taboos are to be noted as told by Mrs. Susan Owl and Margaret Brown a number of years ago.

To narrate stories after dark is to invite annoyance from snakes. If a snake hears a person relating tales it will lie in wait in the path for him or her.

Likewise, if a person mentions aloud his business or intentions regarding travel, a snake may hear it and lie in wait for him. Consequently the wary are advised when about to travel anywhere to speak of going "day after tomorrow" instead of "tomorrow," in order to deceive the snake. Indeed "if he knows where the traveler is going he will try to lie in wait for him!"

[6] Few writers in this field have touched upon the folklore of snakes, and then only to deal briefly with popular beliefs of the American countryside among which the "hoop snake," "milk snake," "glass snake," "swallowing of young" stand out. (See K. P. SCHMIDT and D. D. DAVIS, *Field book of snakes of the United States and Canada*, 1941, for a section on Folklore of Snakes (pp. 7–10) and references to K. P. SCHMIDT and R. V. MEDDEN for more extensive reference to essays on snake lore.) In an article, *The hoop snake story*, K. P. SCHMIDT quotes references to the hoop-snake legend in the South and suggests a Negro origin for it as a possibility (Nat. Hist. 25 (1): 76–90. 1925).

The story is told of an old man years ago who had a watermelon patch visited by girls who would steal them. To keep them out he put white-oak splints around the field and caused them to be transformed into snakes when intruders came.

In Catawba tradition, as far as a conclusion can be reached, all snakes are maleficent, and that means potentially poisonous in their relationship to man. Whether the baneful influences are exerted through spiritual or physiological mediums (fangs or teeth) is not considered to be precisely essential to personal protection and welfare. Only in the case of death and disablement resulting from the bite of rattlesnake, moccasin, or copperhead is observation of cause and effect specified. The hog-nose snake is equally feared, and, in the estimation of some of the people, others as well. Hence snakes may inflict injury and death, through tongues or teeth in direct contact, and inflict sickness, misfortune, or ill fate through mysterious toxic agencies of a spiritual nature. These conceptions are vaguely garbled and vary individually as might be expected among folk whose minds are trained to reason by tradition drawn from two realms, the real and the unreal.

II. The Turtles

The four reptiles of this category recognized by the Catawba are all denoted by the classifying term ka or kayą́, "turtle." The latter term may have semantic relationship with that for snake (ya).

1. kɬ́i, "turtle" (or possibly "scratcher"), box turtle (*Terrapene carolina*).

2. kayą́, "turtle snake" (locally, cooter terrapin), members of the genera *Malaclemys*, *Chrysemys*, and *Pseudemys*, without distinction.

3. kayą́ skąteró, "terrapin head big," snapping turtle (*Chelydra serpentina*).

4. kayą́ səmfˑʔ "terrapin soft," soft-shelled turtle (*Amyda ferox*). The flesh of this creature is prepared and eaten by the Catawba.

The attempt to identify with precision the native names of the musk and mud turtle proved unsuccessful. The following names were taken down as applicable to one or the other:

1. ka səmfˑʔ, "turtle soft," musk turtle, or stinkpot (*Sternotherus odoratus*).

2. kaya tɛfˑreʔ, "terrapin mud (?)," mud turtle (*Kinosternon subrubrum*), also a variant

term kǵi·e applied loosely to both creatures at different times by Mrs. Owl (1920) and Margaret and Sally Brown and Sam Blue in later years.

III. The Lizards

The Catawba denote the saurians by the collective term wapirę́?, "lizard"; one hardly capable of analysis at present unless the primary element wap may have reference to something round in form. Three true lizard forms are recognized as follows. Salamanders are included with them in the Catawba arrangement.

1. wapirę́? hiskǫ́ sǫkǫ́'re, "lizard head red" (locally scorpion), blue-tailed skink (*Eumeces fasciatus*). The name is derived from the reddish head of the fully adult male. The young phase of the reptile with striped back and blue tail was known to the informant correctly as an age phase of the same creature. This knowledge seemed noteworthy for Indians since it is not usually so understood among surrounding whites.

2. wapirę́? wǫ'ka?, "lizard green," American chameleon (*Anolis carolinensis*). The Catawba believe the chromatic stages of the animal to be due to its need to simulate the color of its immediate background.

3. wapirę́?, "lizard," swift or fence lizard (*Sceloporus undulatus*). The tailed amphibians are also included in the nomenclature of lizards, owing to their lizardlike form of body.

4. wapirę́? yǫtci're, "lizard (in) branch (of river or spring)" (*Desmognathus fuscus auriculatus*). Found abundantly on the reservation in the "branches" of Catawba River in the usual haunts under stones, and the informants gave the same native name to all the other varieties known within their range.[7]

IV. The Frogs and Toads

In the native system of zoonomy there seems to be no grouping of the suborders of the Anura, there being but one inclusive term for the family Bufonidae and another for the Hylidae and Ranidae. The distinction usually observed is that of size, which is indicated by suffixes denoting "large" and "small."

1. arǫ́?rai, frog, specifically bullfrog (*Rana catesbeiana*), an inclusive term for all forms of the genus *Rana*. It is onomatopoeic, a native reproduction of the sound impression of the voice of *Rana*, although it referred specifically to the green frog (*Rana clamitans*) as heard in 1946 in the swamps of the reservation. Chief Sam Blue mentioned a belief among the Catawba that when the frog's voice is heard "fish bite well" (arǫ'?rǫi kauhatcu're yi·sóhewe).

2. ka're, frogs known as "knee-deep"[8] (*Hyla, Acris*, and *Pseudacris*, undifferentiated).

3. watcikamú, "(?) suck," toad (*Bufo*, species undifferentiated). Why the same name should apply to the leech remains unexplainable.

An instance of folk belief in linkage by metamorphosis between *Bufo* and *Rana* was given by Margaret Brown, an aged Catawba woman who died in 1922. She related how the people believed that the toad laid eggs "which turn into tadpoles and after a certain length of time these turn into bullfrogs."

CHEROKEE SNAKE NAMES AND IDENTITIES

The following list of 14 species with their Cherokee native names and explanations represents the knowledge possessed by Will West Long, a linguistic purist and traditionalist of the Big Cove settlement, Qualla Reservation of the eastern Cherkokee, Swain County, N. C. Big Cove is an elevated basin (above 3,000 feet) at the foot of the main ridge of the Great Smoky Mountains. In the lower levels of the reservation, however, the Indians are acquainted with more reptilian forms, and such names and identities are added from notes made there recently by John G. Witthoft.

West Long, who knew only the forms in his own district, by his own testimony was unacquainted with the water moccasin, the whip snake, the scarlet snake, the "glass snake," and even the milk snake. Therefore for them he had no native names that could be definitely assigned to species. We found no authoritative sources to check occurrences of these creatures in the district of the Big Cove to which the list applies. A complete local collection of forms found there would be necessary to settle this point of distribution in the immediate neighborhood. West Long, furthermore, disclaimed

[7] Questioning informants about the occurrence of the mudpuppy in Catawba River revealed that it was not known to the Indians of the reservation.

[8] An explanatory folk narrative told by Chief Sam Blue relative to the locally popular name "knee-deep": "Said the bullfrog on the edge of the swamp, 'Come on in!' Another frog cried out, 'How deep?' The tiny peepers called out, 'knee deep'!"

knowledge of the legendary hoop snake. Witthoft, however, obtained a reference to it from other sources.

The lack of correspondence between the Catawba and Cherokee snake lists is accounted for, in part, by the differences in topography of their respective habitats. Certain forms are not known to the mountain regions. Moreover, the two peoples belong to unrelated families of speech (Catawba is of the Siouan linguistic stock, Cherokee is Iroquoian), whence the total nonrelationship of their reptilian terminologies.

In presenting the material from the Cherokee here no attempt is made to include reference to reptile lore of the tribe. The extent and wealth of such matter would require a comprehensive monograph, which would cover much of the religious and ceremonial life of the people. Reptiles, indeed, play a highly important role in Cherokee tradition.

Where the technical designations for snakes correspond with those in the Catawba list they are not repeated.

The Cherokee generic term for snake is i·natą.

1. udzǫ́ natą́', "now you see snake," rattlesnake.

2. kądzét'i·, "rattle," ground rattlesnake. The term is identical with that for the gourd rattle carried in the hand of a dance leader.

3. w'ɔ təgi· askɔ'li·', "brown head," copperhead. Also tsiúk tadzistaí, "with fire eye."

4. ki'zi·dzulí·', "feces has in it," hog-nosed snake. The term is not explainable in origin beyond the possible idea that the forcible hissing of the creature was caused by an excess of substance in its abdomen producing the described condition.

5. ka?lek'gí·', "he climbs up a tree," black snake.

6. ka?lek'gí· at'ą́', "blacksnake young," ringnecked snake. This is regarded as a young phase of the black snake.

7. wuckəlihą́ i·nat'?ąnihé́, "boss snake king," king snake (informant, Amanita Tramper). Neither the animal nor its name was known to West Long.

8. i·nat' ugǫ'wi·yahį, "snake king," milk snake (questionable).

9. gi·gó i·natą́', "red snake," corn snake. West Long had encountered the species only once and was not certain of its identity.

10. uk'suhí·, "substance in the eye," mountain blacksnake. West Long could offer no explanation for the origin of this name.

11. selikwɔ́yí·', "green," smooth green snake (doubtful) and rough green snake.

12. odalí·'ak'tiyà' (odalík' tiyà, shortened form), "mountain guard," yellow-striped chicken snake. The name describes the habit of the creature to lie atop the mountain, among rocks it is said, to watch the movements of other animals. The common idea is that it acts as a guardian observer of life on the mountain. The same term is applied to the garter snake through its similarity in stripes to the preceding. Observation has apparently been lax among the Cherokee in regard to differences in appearance and habit of these reptiles. Some doubt rests in the identity of the 4-lined chicken snake referred to.

13. kənégwɔdí·', "goes underground and pushes soil up," water snake and queen or leather snake. The term is general for all phases of the genus *Natrix*. Color variations are denoted by descriptive terms.

14. i·nát' ąt'í· kalaǫskí·', "snake pottery breaking," worm snake (*Carphophis amoena amoena*). Explanation of this name is beyond the ability of anyone questioned regarding its application. It was stated that if the worm snake is placed on the head of any one infested with lice the vermin will disappear.

Jimsie and Tahquette Wallace, of Adam's Creek, near Birdtown, on the reservation about 16 miles from the Big Cove and at a lower altitude, recognized the following varieties (notes contributed by J. G. Witthoft):

15. djogés aktiyà, garter snake and redbellied brown snake.

16. toledą́, glass snake.

17. onegast ànìistí·', "hoop snake." There are said to be two varieties, neither of which the informants have seen. They are somewhat skeptical about the existence of this snake but say it may have existed in the lowland environment that some of the Cherokee formerly inhabited.

18. waskatí·', milk snake.